BAB 5
DETAIL ENGINEERING DESIGN (DED)

Pada bab ini berisi perhitungan dimensi maupun ukuran dari masing-masing unit pengolahan yang direncanakan dan ukuran lahan yang akan digunakan.

5.1 Saluran Pembawa

- **Kriteria Perencanaan**
  - Kecepatan aliran (v) = 0,3 – 0,6 m/s

    (Sumber : Metcalf & Eddy, Wastewater Engineering Treatment & Reuse, Fourth Edition, hal 316)
  - *Freeboard* = 5% - 30%

    (Sumber : Chow, Ven Te. 1959. Open Channel Hydraulics, hal 159. New York, USA: Mcgraw-Hill Book company, Inc)
  - Koefisien *manning* (n) beton = 0,013

No.	Bahan	Koefisien manning (n)
1.	Besi tuang lapis	0,014
2.	Kaca	0,010
3.	Saluran beton	0,013
4.	Bata dilapisi mortar	0,015
5.	Pasangan batu semen	0,025
6.	Saluran tanah bersih	0,022
7.	Saluran tanah	0,030
8.	Saluran dengan dasar batu dan tebing rumput	0,040
9.	Saluran pada galian batu padas	0,040

(Sumber : Bambang Triatmodjo, 2015, tabel 4.2 harga koefisien manning (n), hal 113)

- **Data Perencanaan**
  - Debit air limbah (Q) = 1100 m³/hari = 0,013 m³/s
  - Kecepatan aliran (v) = 0,38 m/s
  - Freeboard (fb) = 30%
  - Koef. *manning* beton = 0,013
  - Panjang saluran = 5 m
  - Dimensi saluran = W:H ; 1:1

- **Perhitungan**

1. Luas permukaan (A)

   A $= \frac{Q\ (m3/detik)}{V\ (m/detik)}$

   $= \frac{0{,}013\ (m3/detik)}{0{,}38\ (m/detik)}$

   = 0,034 m²

2. Dimensi saluran pembawa

   - Kedalaman Saluran (H)

     H $= \frac{A\ (m2)}{B\ (m)}$

     $= \sqrt{\frac{A}{H}}$

     $= \sqrt{\frac{0{,}034}{1}}$

     = 0,18 m

   - Lebar saluran (W)

     W = H

     = 0,18 m

   - Kedalaman total (H_{total})

     H_{total}= H + *freeboard*

     = H + (30% x H)

     = 0,18 m + (30% x 0,18 m)

     = 0,18 m + 0.04

     = 0,22 m

3. Cek kecepatan saat maksimal (v_{cek})

   v_{cek} $= \frac{Q\ (m3/detik)}{A\ (m2)}$

   $= \frac{Q}{W\ x\ H}$

   $= \frac{0{,}013\ (m3/detik)}{0{,}18\ m\ x\ 0{,}22\ m}$

   = 0,32 m/detik (memenuhi)

4. Jari-jari hidrolis (R)

   R $= \frac{W\ x\ H}{W + 2H}$

$= \frac{0{,}18\ m\ x\ 0{,}22\ m}{0{,}18\ m + (2x0{,}22\ m)}$

= 0,06 m

5. *Slope* saluran (S)

S $= (\frac{n\ x\ v}{R^{0{,}66}})^2$

$= (\frac{0{,}013\ x\ 0{,}32}{0{,}06^{0{,}66}})^2$

= 0,00065 m/m

6. *Headloss* saluran (Hf)

Hf = n x L

= 0,013 x 2 m

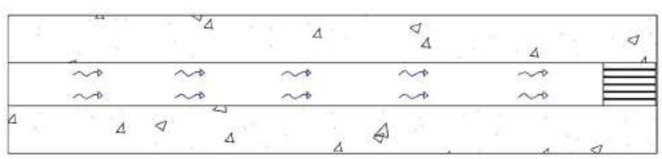
= 0,0325 m

- **Resume**

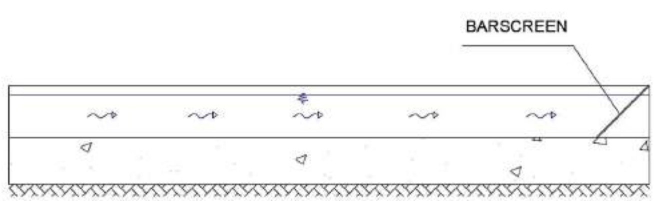
1. Luas permukaan (A) = 0,034 m²
2. Tinggi saluran (H_{total}) = 0,22 m
3. Lebar saluran (W) = 0,18 m
4. Panjang saluran (L) = 2,5 m
5. Jari-jari hidrolis (R) = 0,06 m
6. Slope saluran (S) = 0,00065 m/m
7. Headloss saluran (Hf) = 0,0325 m

- **Sketsa**

- Tampak denah



- Tampak potongan



5.2 *Bar Screen*

- **Kriteria Perencanaan**
  - Lebar kisi (d) = 5 – 15 mm
  - Jarak antar kisi (r) = 25 – 50 mm
  - Kecepatan (v) = 0,3 – 0,6 m/s
  - *Headloss* (Hf) = 150 mm
  - Koef. saat *non clogging* (c) = 0,7
  - Koef. saat *clogging* (Cc) = 0,6
  - Kemiringan kisi = 30° – 45°

  (Sumber: Metcalf & Eddy, Wastewater Engineering Treatment & Reuse, Fourth Edition, hal 316)

- **Data Perencanaan**
  - Menggunakan *bar screen* manual dengan tipe *coarse screen*
  - Debit air limbah (Q) = 1100 m^3/hari □ 0,013 m^3/s
  - Kecepatan aliran (v) = 0,38 m/s
  - *Headloss* (Hf) = 150 mm = 0,15 m
  - Lebar saluran (Ws) = 0,18 m
  - Tinggi *bar screen* = 0,22 m
  - Tinggi muka air (h_{air}) = 0,18 m
  - Lebar kisi (d) = 5 mm → 0,005 m
  - Jarak antar kisi (r) = 26 mm → 0,026 m
  - Sudut kemiringan kisi (θ) = 45°
  - Percepatan gravitasi (g) = 9,81 m/s^2

- **Perhitungan**
  1. Jumlah kisi (n)

     Ws = n.d + (n+1)r

     0,18 m = 0,005n + (n+1)0,026

     0,18 m = 0,005n + 0,026n + 0,026

$0{,}031n = 0{,}154$

$= \frac{0{,}154}{0{,}031}$

= 4,9 → 5 Batang

2. Panjang sisi miring (x)

X $= \frac{Tinggi\ Saluran}{Sin\ a}$

$= \frac{0{,}22\ m}{Sin\ 45}$

= 0,311 m

3. Panjang *bar screen* (Y)

Y $= \sqrt{X^2 - H^2}$

$= \sqrt{0{,}31^2 - 0{,}22^2}$

= 0,22 m

4. Kecepatan melalui *bar screen* (Vi)

Vi $= \frac{Q}{Wc\ x\ h\ air}$

$= \frac{0{,}013\ m3/s}{0{,}16\ m\ x\ 0{,}18\ m}$

= 0,45 m/s (memenuhi)

5. *Headloss* saat bersih (Hf)

Hf $= \frac{1}{C}\left(\frac{Vi^2 - V^2}{2g}\right)$

$= \frac{1}{0{,}7}\left(\frac{0{,}45^2 - 0{,}38^2}{2x9{,}81}\right)$

= 0,00413 m < 0,15 m (memenuhi)

6. *Headloss* saat *clogging* (Hf)

Kecepatan melalui bar screen tersumbat diestimasi meningkat 50% *(Sumber: Metcalf & Eddy, Wastewater Engineering Treatment & Reuse, Fourth Edition, hal 316)*

Wc = Ws - (n x d)

= 0,18 - (5 x 0,005)

= 0,155

Vc $= \frac{Q}{50\%.Wc.h\ air}$

= 0,9 m/s

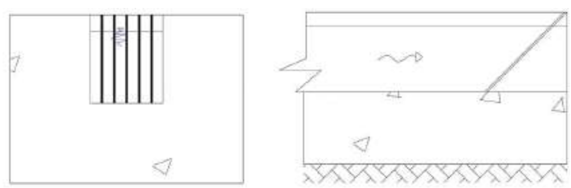
Hf $= \frac{1}{Cc}\left(\frac{Vc^2 - Vi^2}{2g}\right)$

$= \frac{1}{0,6}\left(\frac{0,9^2 - 0,38^2}{2x9,81}\right)$

= 0,05126 m < 0,15 m (memenuhi)

- **Resume**
  1. Jumlah kisi = 5 batang
  2. Lebar kisi (d) = 5 mm → 0,005 m
  3. Jarak antar kisi (r) = 26 mm → 0,026 m
  4. Panjang sisi miring (X) = 0,311 m
  5. Panjang bar screen (Y) = 0,13 m
  6. Tinggi bar screen (H) = 0,22 m
  7. Kecepatan melalui bar screen (Vi) = 0,45 m/s

- **Sketsa**



5.3 Bak Ekualisasi

- **Kriteria Perencanaan**
  - Waktu detensi (td) = 1 - 4 jam

    (Sumber : Reynolds, Tom D., Paul A. Richards. 1996. Unit Operations and Processes in Environmental Engineering 2nd edition, hal 161)
  - Tebal dinding = 0,2 m
  - *Freeboard* (fb) = 10% - 20%
  - Kecepatan aliran (v) = 0,3 - 0,6 m/s

    (Sumber: Metcalf & Eddy, Wastewater Engineering Treatment & Reuse, Fourth Edition, hal 316)
  - Kedalaman bak (H) = < 4 m

- Kecepatan aliran *outlet* (v) = 0,3 m/s – 0,6 m/s
- *Kinetic coefficient for plywood industry wastewater*
  1. Y (mg VSS/mg BOD) = 0,64
  2. Kd (day-1) = 0,03

  (*Sumber: Lateef, A., Chaundhry, M. N., & Ilyas, S. 2013. Biological Treatment of Dairy Wastewater using Activated Sludge. ScienceAsia, 39(2), 179-185*)
- Koefisien kekasaran pipa (K)
  1. *Elbow* 90° = 1,1
  2. *Gate valve* = 0,2
  3. *Check valve* = 2,5
  4. *Tee* = 1,0
  5. *Increaser* = 0,5

  (*Sumber: Kawamura, S. 2000. Intergrated Design and Operation of Water Treatment Facilities 2nd, hal: 159. New York: John and Sons, Inc*)

- **Data Perencanaan**
  - Jumlah unit (n) = 1 buah
  - Debit air limbah (Q) = 1100 m^3/hari → 0,013 m^3/s
  - Waktu detensi (td) = 1 jam → 3600 detik
  - Kecepatan aliran (v) = 0,38 m/s
  - Rasio L:W = 2:1
  - Tinggi unit (H) = 2,5 m
  - *Freeboard* (fb) = 20%

- **Perhitungan**
  1. Volume bak ekualisasi

     V = Q x td

     = 0,013 m^3/detik x 3600 detik

     = 45,8 m^3
  2. Dimensi bak ekualisasi

V = W x L x H

45,8 m³ = W x 2W x 2,5 m

45,8 m³ = 5W²

W = $\sqrt{\frac{45,8\ m^3}{5}}$

= 3 m

Maka :

L = 2W

= 2 x 3 m

= 6 m

Tinggi total (H total)

H_{total} = H + (20% x H)

= 2,5 m + (20% x 3 m)

= 2,5 m + 0,5 m

= 3 m

3. Cek volume maksimum

V_{maks} = L x W x H_{total}

= 6 m x 3 m x 3 m

= **54 m³** (memenuhi persyaratan > 45,8 m³)

4. Diameter pipa *outlet*

A = $\frac{Debit\ (Q)}{Kecepatan\ (V)}$

= $\frac{0{,}013\ m3/s}{0{,}38\ m/s}$

= 0,034 m²

D = $\sqrt{\frac{4\ x\ A}{\pi}}$

= $\sqrt{\frac{4\ x\ 0{,}034}{3{,}14}}$

= 0,207 m

Berdasarkan pipa yang ada di pasaran, didapatkan diameter sebesar **216 mm** atau **8 inch** merek rucika.

KELAS D

Diameter		Tebal Dinding (mm)	Panjang (m)	Sistem Penyambungan	Kode Produk
inch	mm				
1-1/4	42	1,30	4	SC	510042001
1-1/2	48	1,30	4	SC	510048001
2	60	1,30	4	SC	510060001
2-1/2	76	1,40	4	SC	510076001
3	89	1,60	4	SC	510089001
4	114	2,00	4	SC	510114001
5	140	2,60	4	SC	510140001
6	165	3,00	4	SC	510165001
8	216	4,20	4	SC	510216001
10	267	5,20	4	SC	510267001
12	318	6,20	4	SC	510318001

SC : Solvent Cement (Penyambungan dengan Lem)

Cek kecepatan pipa outlet

$$v = \frac{Q}{A}$$

$$= \frac{0{,}013\ m^3/s}{\frac{1}{4} x\ \pi\ x\ D^2}$$

$$= \frac{0{,}013\ m^3/s}{\frac{1}{4} x\ 3{,}14\ x\ (0{,}216\ m)^2}$$

= 0,4 m/s (memenuhi persyaratan antara 0,3 m/s – 0,6 m/s)

5. Konsentrasi rata-rata BOD dalam aliran ke luar dari bak (Xoc)

$$Xoc = \frac{ViC.XiC + Vsp.Xsp}{ViC + Vsp}$$

$$= \frac{(45{,}8\ m3\ x\ 890\ g/m3) + (45{,}8\ m3\ x\ 133{,}5\ g/m3)}{45{,}8\ m3 + 45{,}8\ m3}$$

$$= \frac{40762\ g + 6114{,}3\ g}{91{,}6\ m3}$$

= 511,75 g/m^3

Keterangan :

ViC = Debit awal masuk bak

XiC = Konsentrasi parameter awal masuk bak

Vsp = Debit keluar dari bak

Xsp = Konsentrasi parameter yang lolos dan keluar dari bak

Xoc = Total konsentrasi parameter yang teremoval di bak

6. *Mass loading rate* (M_{rate})

M_{rate} = Xoc x Q

= 511,75 g/m3 x 0,013 m3/s

= 6,52 g/s → 562,93 kg/hari

7. Koefisien batas pertumbuhan (Y)

$Y = Y_{20} \times \theta^{(T-20)}$

$= 0,64 \times 1,04^{(30-20)}$

= 0,95 mg $^{VSS}/_{mg}$ BOD$_5$

8. Kuantitas lumpur perhari

$$Y_{obs} = \frac{Y}{1 + kd.\theta c}$$

$$= \frac{0,95}{1+(0,03 \times 10)}$$

= 0,66 mg $^{VSS}/_{mg}$ BOD

Menentukan koefisien *endogenous*

$kd = kd_{20} \times \theta^{(T-20)}$

$= 0,03 \times 1,04^{(30-20)}$

= 0,04/hari

9. Massa lumpur

$\rho_x = Y_{obs} \times Q\ (Ca\text{-}Cr)$

= 0,66 x 1100 m3/hari (890 – 133,5)

= 545915,91 g/hari → 545,92 kg/hari

Keterangan :

T = Suhu

Y = *Biomassa yield*

Θ = Temperatur *activity coef*

Θ_c = Umur lumpur (5 – 15)

10. Jumlah beban

$$\text{Beban} = \frac{Q.(Ca - Cr)}{F}$$

$$= \frac{1100 \times (0,89-0,1335)}{0,8}$$

= 665,72 $^{Kg}/_{Hari}$

= **27,74 $^{Kg}/_{Jam}$**

11. Jumlah Oksigen yang diperlukan tiap hari

Kebutuhan total O_2 = jumlah beban BOD + (1,42 x ρ_x)

= 665,72 kg/hari + (1,42 x 545,92 kg/hari)

= 1440,92 kg O_2/hari → 27,74 kg/jam

Berdasarkan kebutuhan oksigen yang dibutuhkan, diperlukan *surface aerator* SAR-330 untuk memenuhi kebutuhan oksigen dengan kapasitas transfer oksigen sebesar 31,0 kg/jam.

Type	Motor		Surface Aerator				
	Power (hp)	Speed (r/min)	OC-HR (kg/h)	MD (m)	MZ (m)	D (m)	PR (m^3/min)
SAR-32	2	1450	3.0	6	12	2~3	5
SAR-33	3	1450	4.2	9	18	3~4	7
SAR-35	5	1450	6.6	12	24	3~4	9
SAR-37	$7^1/2$	1450	9.6	16	32	3~4	11
SAR-310	10	1450	11.5	19	38	3~4	19
SAR-315	15	1450	16.5	27	54	3~4	24
SAR-320	20	1450	21.0	32	64	3~4	29
SAR-325	25	1450	27.5	36	72	3~4	33
SAR-330	30	1450	31.0	40	80	3~4	37
SAR-340	40	1450	38.0	45	90	5~6	46
SAR-350	50	1450	50	50	100	5~6	55
SAR-360	60	1450	61	56	112	5~6	65
SAR-375	75	1450	73	62.5	125	5~6	80
SAR-3100	100	1450	95	70	140	5~6	120

MZ: Diameter of Mixing Zone. (m)
OC-HR: Kgs Oxygenation Capacity per Hour. (kg/h)
MD: Diameter of Complete Mixing in Meter at minimum average velocity of 1.2 meter per second (approx). (m)
D: Depth in Meter of Complete Mixing, related to MD.
PR: Pumping Rate, m^3 per Minute.

Perhitungan Pompa Menuju Bak Pengendap 1

- **Kriteria Perencanaan**
  - K Elbow 90^0 = 0,9

    (*Sumber: Dake, J.M.K., Endang P. Tachyan dan Y.P. Pangaribuan, 1985. "Hidrolika Teknik* Edisi II", Erlangga. Jakarta)
  - K reducer = 0,25

    (*Sumber: Practical Hydrolics For The Public Work Engineer, 1968*)

- **Data perencanaan**
  - Elbow 90^0 suction = 1 buah
  - Elbow 90^0 discharge = 2 buah
  - Increaser suction = 1 buah
  - Increaser discharge = 1 buah
  - Q bak = 0,013 m3/s → 1123,2 m^3/hari
  - L suction = 7,84 m
  - L discharge = 2,87 m

- Diameter pipa = 0,20 m → 8 inch
- Kecepatan pipa (v) = 0,4 m/s
- Head statis = 1,9 m

- **Perhitungan**

1. Perhitungan suction

   Headloss mayor

   Hf $= \frac{10.7\ x\ L\ x\ Q^{1.85}}{C^{1.85}\ x\ D^{4.87}}$

   $= \frac{10.7\ x\ 7,84\ m\ x\ (0.013\ m3/detik)^{1.85}}{130^{1.85}\ x\ 0.20\ m^{4.87}}$

   = 0,0085 m

   Headloss minor (elbow)

   Hf_{elbow} $= n\ x\ k\ x\ \frac{v^2}{2g}$

   Hf_{elbow} $= (1\ x\ 0.9\ x\ \frac{0.4\ m/s^2}{2\ x\ 9.81\ m/s2})$

   = 0,0073 m

   Headloss minor (reducer)

   $Hf_{reducer}$ $= n\ x\ k\ x\ \frac{v^2}{2g}$

   $Hf_{reducer}$ $= (1\ x\ 0.25\ x\ \frac{0.4\ m/s^2}{2\ x\ 9.81\ m/s2})$

   = 0,002 m

   ∑Hf minor

   Hf_{minor} = Hf minor elbow + Hf minor reducer

   = 0,0073 + 0,002

   = 0,0094

   ∑Hf suction

   Hfs = Hf mayor + Hf minor

   = 0,0085 m + 0,0094 m

   = 0,0178 m

2. Perhitungan Discharge

   Headloss mayor

Hf $= \frac{10.7 \ x \ L \ x \ Q^{1.85}}{C^{1.85} \ x \ D^{4.87}}$

$= \frac{10.7 \ x \ 2{,}87 \ m \ x \ (0.013 \ m3/detik)^{1.85}}{130^{1.85} \ x \ 0.20 \ m^{4.87}}$

= 0,0031 m

Headloss minor (elbow)

Hf_{elbow} = n x k x $\frac{v^2}{2g}$

Hf_{elbow} = (2 x 0.9 x $\frac{0.4 \ m/s^2}{2 \ x \ 9.81 \ m/s2}$)

= 0,0147 m

Headloss minor (increaser)

Hf_{elbow} = n x k x $\frac{v^2}{2g}$

Hf_{elbow} = (1 x 0.25 x $\frac{0.4 \ m/s^2}{2 \ x \ 9.81 \ m/s2}$)

= 0,002 m

∑Hf minor

Hf_{minor} = Hf minor elbow + Hf minor increaser

= 0,0147 + 0,002

= 0,0167

∑Hf discharge

Hfd = Hf mayor + Hf minor

= 0.0031 m + 0.0167 m

= 0.0198 m

3. Perhitungan Head total

Head total = Head statis + ∑Hf suction + ∑Hf discharge

= 1,9 m + 0.0178 m + 0.0198

= 1,94 m

4. Perhitungan Head pompa

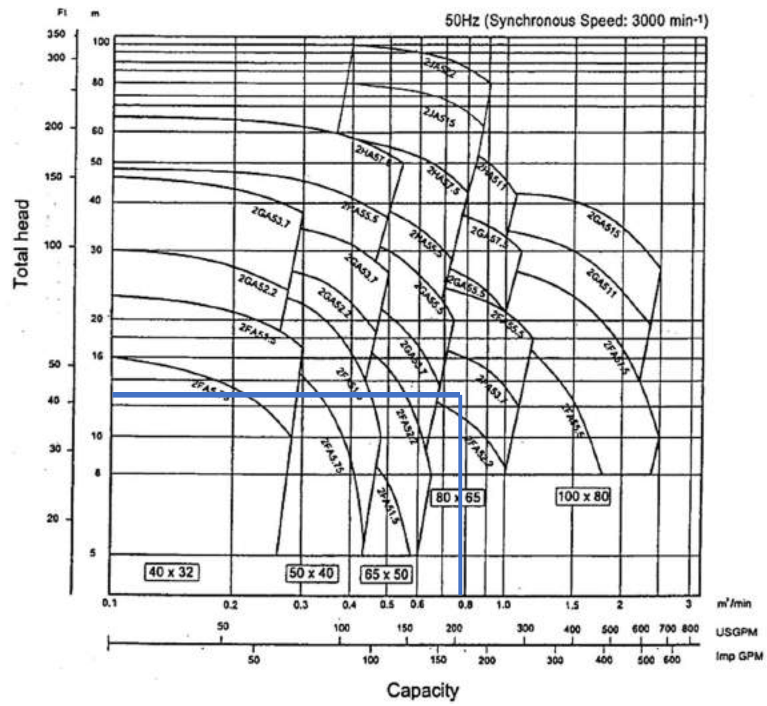
Head pompa = Head statis + L suction + L discharge

= 1,9 m + 7,84 m + 2,87 m

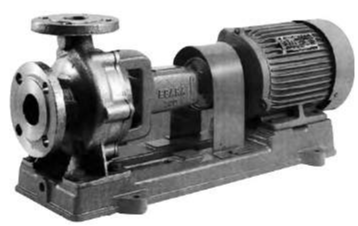
= 12,61 m

Head pompa > Head total

12,61 m > 1,94 m (memenuhi persyaratan)



Berdasarkan grafik di atas, maka dipilih pompa dengan merek Ebara dengan tipe 80 x 65 FSSFA53,7 dengan spesifikasi yang tertera pada lampiran A.

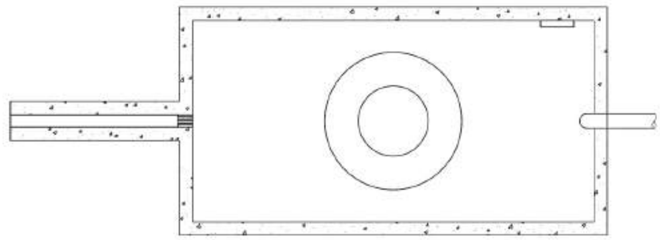


- **Resume**

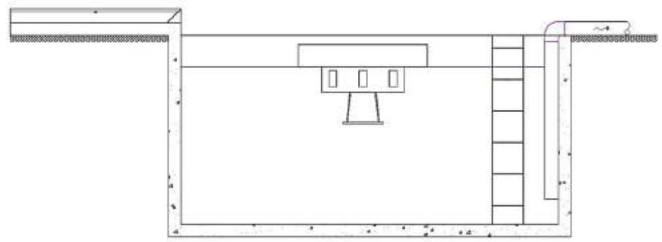
1. Volume bak = 45,8 m³
2. Lebar bak (W) = 3 m
3. Panjang bak (L) = 6 m
4. H total bak = 3 m
5. Diameter pipa outlet = 0,216 m → 8 inch

- **Sketsa**

- Tampak denah



- Tampak potongan



5.4 Bak Pengendap 1

A. Zona Pengendapan (*Settling Zone*)

- **Kriteria Perencanaan**
  - Bentuk bak sedimentasi = *rectangular*
  - Kedalaman (H) = 3 – 4.9 m
  - *Flight Speed* = 0.6 – 1.2 m/menit
  - Waktu Detensi (Td) = 1.5 – 2.5 jam

  (*Sumber: Metcalf & Eddy, Wastewater Engineering Treatment & Reuse, 4th Edition, hal 398***)**

  - Massa jenis air (ρ), T = 28°C = 996,36 kg/m^3
  - Viskositas kinematik (υ) = 0,8036 x 10^{-6} m^2/s
  - Viskositas dinamik (μ) = 0,8363 x 10^{-3} N s/m^2

  (*Sumber: Reynolds, Tom D. dan Paul A. Richards. 1996. Unit Operations and Processes in Environmental Engineering 2nd edition, hal 762 (Appendix C). Boston: PWS Publishing Company***)**

  - Specific gravity solid (Ss) = 1.4
  - Specific gravity sludge (Sg) = 1.02

(*Sumber: Metcalf & Eddy, Wastewater Engineering Treatment & Reuse, 4th Edition, hal 1456*)

- Bilangan Reynold (Nre) untuk Vs <1 (aliran laminar)

  (*Sumber: Reynolds, Tom D. dan Paul A. Richards. 1996. Unit Operations and Processes in Environmental Engineering 2nd edition, hal 224. Boston: PWS Publishing Company*)
- Kemiringan dasar bak = 1 – 2%
- Bilangan Reynold (Nre) untuk Vh <2000 (aliran laminar)
- Bilangan Froude (Nfr) = $>10^{-5}$

  (*Sumber: SNI 6774 Tata Cara Perencanaan Unit Paket Instalasi Pengolahan Air 2008, hal 6*)

- **Data Perencanaan**
  - Debit air limbah (Q) = 0,013 m^3/s
  - Waktu detensi (td) = 2,3 jam → 8280 s
  - Kemiringan *plate settler* = 60^0
  - Panjang *plate settler* = 2/3 Panjang zona pengendapan
  - Lebar *plate settler* = 0,1 m
  - Tinggi *plate settler* = 1,5 m
  - Jarak antar *plate settler* = 5 cm → 0,05 m
  - Kedalaman bak (H) = 3 m
  - Freeboard = 10% x H

- **Perhitungan**
  1. Volume bak pengendap (V)

     V = Q x td

     = 0,013 m^3/s x 8280 s

     = 107,64 m^3
  2. Luas permukaan (A)

     A $= \frac{V}{H}$

$= \frac{107,64 m3}{3\ m}$

= 35,88 m²

3. Dimensi bak pengendap

A = L x W

= 3W x W

= $3W^2$

W = $\sqrt{\frac{A}{3}}$

= $\sqrt{\frac{35,88\ m2}{3}}$

= 3,45 m → 3,5 m

L = 3 x W

= 3 x 3,5 m

= 10,5 m

H **= 3 m**

H_{tot} = H + Freeboard

= H + (10% x H)

= 3 m + (10% x 3 m)

= 3 m + (0,3 m)

= 3,3 m

4. Cek volume max (V_{max})

V_{max} = L x W x H_{tot}

= 10,5 m x 3,5 m x 3,3 m

= **121,275 m³**

5. Cek waktu detensi (td_{cek})

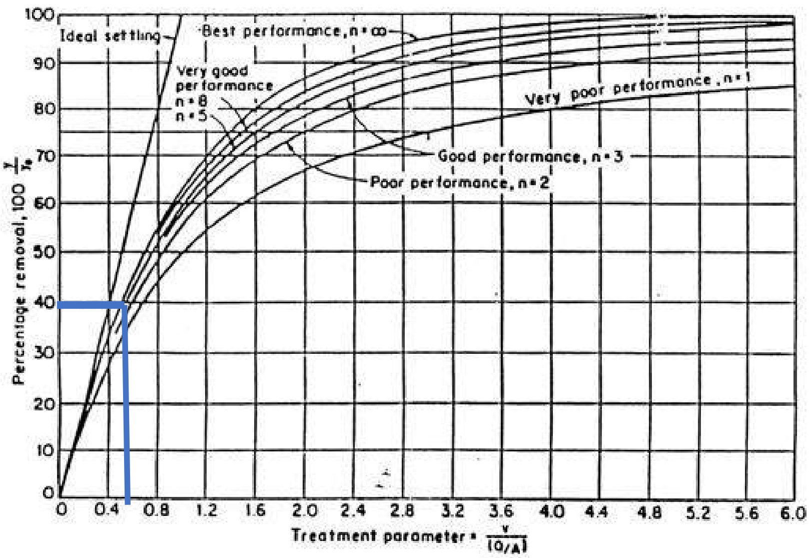
td_{cek} $= \frac{Vmax}{Q}$

$= \frac{121,275\ m3}{0,013\ m3/s}$

= **9238 s → 2,5 jam**

6. Kecepatan pengendapan partikel (Vs)

%removal yang diinginkan = 40%



Direncanakan bak pengendap meremoval 40% kadar TSS, dari grafik good performance diperoleh nilai 0,56 untuk v/(Q/A)

$$\frac{vs}{\left(\frac{Q}{A}\right)} = 0{,}56$$

$$\frac{vs}{\left(\frac{0.013\ m3/s}{3{,}5\ m\ x\ 10{,}5\ m}\right)} = 0{,}56$$

vs **= 0.000198 m/s → 1,98 x 10^{-4} m/s**

7. Diameter partikel (Dp)

$$Dp = \sqrt{\frac{V_S\ x 18\ x\ v}{g\ (Ss-1)}}$$

$$= \sqrt{\frac{0.000198\ m/s\ x\ 18\ x\ 0.8039\ x\ 10^{-6}\ m2/s}{9.81\ m2/s\ (1.4-1)}}$$

= 0,000027 m → 2.7 x 10^{-5} m

8. Jari-jari hidrolis (R)

$$R = \frac{W\ x\ H}{W+(2\ X\ H)}$$

$$= \frac{3{,}5\ m\ x\ 3\ m}{3{,}5\ m + (2\ x\ 3\ m)}$$

= 1,11 m

9. Massa jenis solid (ρs)

$$Sg = \frac{\rho s}{\rho}$$

1,03 $= \frac{\rho s}{1200\ kg/m^3}$

ρs **= 1236 kg/m³**

10. Kecepatan Horizontal (Vh)

Vh $= \frac{Q}{W x\ H}$

$= \frac{0{,}013\ m3/s}{3{,}5\ m\ x\ 3\ m}$

= 0,00124 m/s → 1,24 x 10^{-3} m

11. Cek Bilangan Reynold (Nre)

Nre $= \frac{vh\ x\ R}{v}$

$= \frac{0{,}00124\ m/s\ x\ 1{,}11\ m}{0{,}8039\ x\ 10^{-6}\ m2/s}$

= 1709 (Memenuhi syarat, Nre < 2000)

12. Cek bilangan Froude (Nfr)

Nfr $= \frac{Vh}{\sqrt{g\ x\ H}}$

$= \frac{0{,}00124\ m/s}{\sqrt{9{,}81\ m/s2\ x\ 3\ m}}$

= 0,000236 m → 2,36 x 10^{-4}

(memenuhi syarat > 10^{-5})

13. Kecepatan penggerusan (Vsc)

Vsc $= \sqrt{\frac{8\ x\ \beta\ x\ g\ x\ (ps-pw) x\ NFr}{\lambda\ x\ pw}}$

$= \sqrt{\frac{8\ x\ 0{,}05\ x\ 9{,}81\ x\ (1236-996{,}36)\ x\ 2{,}36\ x\ 10^{-4}}{0{,}03\ x\ 996{,}36}}$

= **0.08 m/s > 0.00124 m/s**

(Vsc > Vh memenuhi, tidak terjadi penggerusan)

14. Kemiringan dasar bak (S)

S = 1% x L

= 1% x 10,5 m

= 0,105 m/m

15. Panjang miring plate settler (Lp)

Lp $= \frac{Tinggi\ plate\ settler\ (Hp)}{\sin 60^0}$

$= \frac{1,5\ m}{0,866}$

= 1,73 m

16. Panjang area plate settler (Lps)

Lps = 2/3 x L

= 2/3 x 10,5 m

= 7 m

17. Jumlah plate settler (np)

n $= \frac{Lps - S}{Sps + Wps}$

$= \frac{7\ m - 0,05\ m}{0,05\ m + 0,1\ m}$ **= 46,33 buah → 46 buah**

- **Resume Bangunan**
  - Panjang bak (L) = 10,5 m
  - Lebar bak (W) = 3,5 m
  - Tinggi bak (H) = 3 m
  - Freeboard (Fb) = 0,3 m
  - Tinggi total bak (H_{tot}) = 3,3 m
  - Kemiringan *plate settler* = 60^0
  - Lebar *plate settler* = 0,1 m
  - Tinggi *plate settler* = 1,5 m
  - Jarak antar *plate settler* = 5 cm → 0,05 m
  - Panjang miring plate settler = 1,73 m
  - Panjang area plate settler = 7 m
  - Jumlah plate settler = 46 buah

B. Zona Lumpur (*Sludge Zone*)

- **Kriteria Perencanaan**
  - Berat jenis air (ρw) = 996,36 kg/m^3

(*Sumber: Reynolds, Tom D. dan Paul A. Richards. 1996. Unit Operations and Processes in Environmental Engineering 2nd edition, hal 762 (Appendix C). Boston: PWS Publishing Company*)

- Specific Solid (Ss) = 1.4

  (Sumber: Metcalf & Eddy, Wastewater Engineering Treatment & Reuse, 4th Edition, hal 1456)

- **Data Perencanaan**
  - Debit air baku (Q) = 0,03 m3/s
  - Persen removal TSS = 40%
  - Persen removal BOD = 15%
  - Kadar TSS dalam air = 390 mg/L
  - Kadar BOD dalam air = 890 mg/L
  - Kadar kepadatan lumpur = 5%
  - Periode pengurasan = 1 hari
  - Ruang lumpur = limas terpancung
  - Panjang atas zona lumpur = 3,5 m
  - Lebar atas zona lumpur = 4 m
  - Panjang bawah zona lumpur = 3 m
  - Lebar bawah zona lumpur = 3 m

- **Perhitungan**
  1. BOD yang teremoval = %Removal x BOD Influent

     = 15% x 890 mg/l

     = 133,5 mg/L → 0,1335 kg/m^3
  2. TSS yang teremoval

     TSS teremoval = %Removal x Kadar TSS

     = 40% x 440 mg/l

     = 156 mg/L → 0,156 kg/m^3
  3. Berat lumpur (Ws)

     Ws = Q limbah x TSS removal x BOD removal

$= 0.013\ m^3/s \times 0.156\ kg/m^3 \times 0,1335\ kg/m^3$

= 0.00027 kg/s → 23,39 kg/hari

4. Berat air

Ww $= \left(\frac{\text{Kadar air dalam lumpur}}{\text{kadar padatan dalam lumpur}}\right) \times Ws$

$= \left(\frac{95\%}{5\%}\right) \times 23{,}39\ kg/hari$

= 444,41 kg/hari

5. Berat jenis lumpur (ρs)

ρs = (SS x 5%) + (Ww x 95%)

= (1,4 x 5%) + (444,41 kg/hari x 95%)

= 422,26 kg/m³

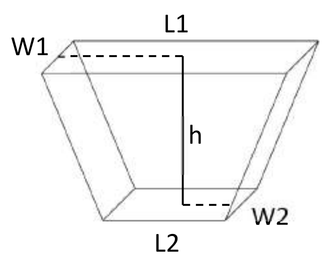
6. Volume Lumpur

V sludge $= \frac{\text{berat lumpur (Ws)} + \text{berat air (Ww)}}{\text{Berat jenis lumpur } (\rho s)} \times tp$

$= \frac{23{,}39\ kg/hari + 422{,}26\ kg/hari}{946{,}61\ kg/m3} \times 1\ jam$

= 18,57 m³

7. Dimensi zona lumpur



a. Luas permukaan atas zona lumpur

A = L1 x W1

= 3,5 m x 4 m

= 14 m²

b. Luas permukaan dasar zona lumpur

A’ = L2 x W2

= 3 m x 3 m

= 9 m²

V limas terpancung = $\frac{1}{3}$ x H x (A + $\sqrt{AA'}$ + A')

18,57 m^3 = $\frac{1}{3}$ x H x (14 + $\sqrt{14 \ x \ 9}$ + 9)

18,57 m^3 = $\frac{1}{3}$ x H x 27,8

18,57 m^3 = 9.26 x H

H = 2 m

- **Resume Bangunan**
  - Panjang atas zona lumpur (L1) = 4 m
  - Lebar atas zona lumpur (W1) = 3,5 m
  - Panjang bawah zona lumpur (L2) = 3 m
  - Lebar bawah zona lumpur (W2) = 3 m
  - Tinggi zona lumpur (H) = 2 m

C. Zona Pelimpah (*Overflow Zone*)

- **Kriteria Perencanaan**
  - *Weir loading rate* = 125 – 500 m^3/m.hari

    (Sumber: Metcalf & Eddy, Wastewater Engineering Treatment & Reuse 4th Edition, hal 398*)*
  - Koefisien drag (Cd) = 0,548
  - Sudut V notch = 45^0
  - *(Sumber: Qasim, dkk., 2000, Water Works Engineering Planning, Design, and Operation)*

- **Data Perencanaan**
  - Zona outlet bak sedimentasi ini berupa weir bergerigi (v-notch)
  - Bentuk gutter = persegi panjang
  - 1 gutter = 2 pelimpah
  - Lebar V notch = 0,1 m
  - Jarak antar V notch = 0,05 m

- Sudut V notch = 45º
- Weir loading (m^3/m.hari) = 350 m^3/m^2.hari → 4 x 10^{-3} m^3/m^2.s
- Q unit sedimentasi = 0,12 m^3/s
- Jumlah unit outlet = 1 buah
- Cd (koefisien drag) = 0,6

- **Perhitungan**

1. Panjang total weir (Lw)

$$Lw = \frac{Q\ bak}{WRL}$$

$$= \frac{0{,}013\ \ m^3/s}{0{,}004\ m^3/m^2.s}$$

$$\mathbf{= 3{,}25\ m}$$

2. Panjang pelimpah (L)

$$L = \frac{Lw}{jumlah\ pelimpah}$$

$$= \frac{3{,}25\ m}{4\ buah}$$

$$\mathbf{= 0{,}8125\ m \rightarrow 1\ m}$$

3. Debit tiap pelimpah (weir)

$$Q = \frac{Q}{n}$$

$$= \frac{0{,}013\ m^3/s}{4\ buah}$$

$$\mathbf{= 0{,}00325\ m^3/s}$$

4. Luas saluran gutter

$$A = \frac{Q\ weir}{v}$$

$$= \frac{0{,}00325\ m3/s}{0{,}6\ m/s}$$

$$\mathbf{= 0{,}00541\ m^2}$$

5. Tinggi (H) dan Lebar (W) Pelimpah (gutter)

Direncanakan H:W = 1 : 2 maka :

$$H = \sqrt{2\ x\ A}$$

$$= \sqrt{2\ x\ 0{,}00541\ m^2}$$

= 0,10 m → 0,1 m

W = 2 x H

= 2 x 0,1 m

= 0,2 m

6. Ketinggian air pada pelimpah (H air)

H air $= \left(\frac{Q\ weir}{1{,}38\ x\ lebar\ gutter}\right)^{2/3}$

$= \left(\frac{0{,}00325\ m^3/s}{1{,}38\ x\ 0{,}2\ \ m}\right)^{2/3}$

= 0,05 m → 5 cm

7. Tinggi gutter (h gutter)

H gutter = h air + (h air x 20%)

= 0,05 m + (0,05 x 0,2)

= 0,06 m → 6 cm (memenuhi 0,1 m)

8. Jari- jari hidrolis gutter

R gutter $= \frac{h\ air\ x\ lebar\ gutter}{(2\ x\ h\ air) + lebar\ gutter}$

$= \frac{0{,}05\ m\ x\ 0{,}2\ m}{(2\ x\ 0{,}05\ m) + 0{,}2\ m}$

= 0,03 m

9. Luas basah gutter (A gutter)

A = Lebar gutter x h air

= 0,2 m x 0,05 m

= 0,1 m

10. Slope gutter (S)

S $= \left(\frac{Q\ gutter\ x\ n}{A\ gutter\ x\ (R\ gutter)^{2/3}}\right)^2$

$= \left(\frac{0{,}00325\ m^3/s\ \ x\ 0{,}013}{0{,}1\ m\ x\ (0{,}03\ m)^{2/3}}\right)^2$

= 0,000019 m/m → 1,9 x 10^{-5} m/m

11. Headloss pada gutter

Hf = L gutter x S gutter

= 1 m x 0,000019 m/m

= 0,000019 m

12. Jumlah V notch

$$n = \frac{panjang\ weir}{jarak\ antar\ V\ notch + lebar\ V\ notch}$$

$$= \frac{1\ m}{0{,}05+0{,}1}$$

= 6,6 buah → 7 buah

13. Debit mengalir tiap V notch

$$Qnotch = \frac{Q}{jumla\quad V\ notch}$$

$$= \frac{0{,}013\ m^3/detik}{7\ buah}$$

= 0,00185 m3/s → 1,85 x 10^{-3} m3/s

14. Tinggi peluapan melalui V notch (H)

$$Q = \frac{8}{15}\,(Cd)\,\sqrt{2\ x\ g}\ x\ \tan\frac{\theta}{2}\ x\ H^{5/2}$$

$$0{,}013\ m^3/s = \frac{8}{15}\,(0{,}6)\,\sqrt{2\ x\ 9{,}81}\ x\ \tan\frac{45}{2}\ x\ H^{5/2}$$

H = 0,01547 m → 1,547 cm

- **Resume Bangunan**
  - Jumlah *gutter* = 2 buah
  - Jumlah *weir* = 4 buah
  - Panjang *gutter* = 1 m
  - Tinggi *gutter* = 0,1 m
  - Lebar *gutter* = 0,2 m
  - Tinggi air limpahan = 0,05 m → 5 cm
  - Kemiringan dasar *gutter* = 0,000019 m/m
  - Jumlah V *notch* = 7 buah
  - Tinggi peluapan V *notch* = 0,01547 m → 1,547 m

D. Zona *Outlet*

- **Data Perencanaan**
  - Debit air baku (Q) = 0,12 m3/s
  - Waktu detensi (Td) = 5 menit → 300 s
  - Lebar saluran = 3,5 m

- Tinggi saluran = 3 m
- Kecepatan aliran pipa outlet = 1 m/s

- **Perhitungan**
  1. Volume saluran pengumpul (V)

     V = Debit (Q) x waktu detensi (td)

     = 0,013 m^3/s x 600 s

     = 7,8 m^3
  2. Dimensi Saluran

     V = L x W x H

     7,8 m^3 = L x 3,5 m x 3 m

     7,8 m^3 = L x 10,5 m^2

     L $= \frac{7,8\ m2}{10,5\ m3}$

     = 0,74 m → 0,75 m

     H **= 3 m**

     H_{tot} = H + *Freeboard*

     = H + (10% x H)

     = 3 m + (10% x 3 m)

     = 3 m + (0,3 m)

     = 3,3 m
  3. Jari-jari hidrolis (R)

     R $= \frac{\text{L x H}}{\text{L + (2 x H)}}$

     $= \frac{\text{0,75 m x 3 m}}{\text{0,75 m + (2 x 3 m)}}$

     = 0,33 m
  4. Luas penampang pipa (A)

     A $= \frac{Debit\ air\ (Q)}{kecepaatan\ aliran\ (v)}$

     $= \frac{\text{0,013 m3/s}}{0,5\ m/s}$

     = 0,026 m^2
  5. Diameter pipa (D)

D $= \sqrt{\frac{4 \ x \ A}{\pi}}$

$= \sqrt{\frac{4 \ x \ (0,026) \ m^2}{3,14}}$

= 0,18 m → 7,08 inch

Berdasarkan tabel di atas maka dipilih pipa sebesar 8 inch (20 mm)

6. Cek kecepatan (v_{cek})

v_{cek} $= \frac{\text{Debit air (Q)}}{\text{luas penampang pipa (A)}}$

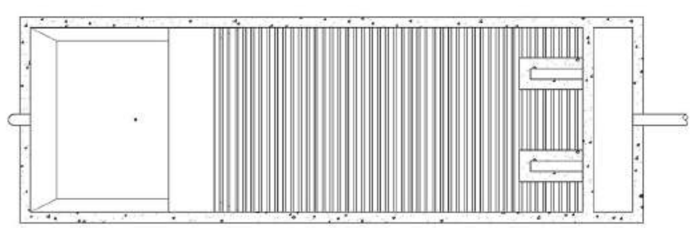
$= \frac{Q}{\frac{1}{4} x \ \pi \ x \ D^2}$

$= \frac{0,013 \text{ m3/s}}{\frac{1}{4} x \ 3,14 \ x \ 0,2^2 \ m}$

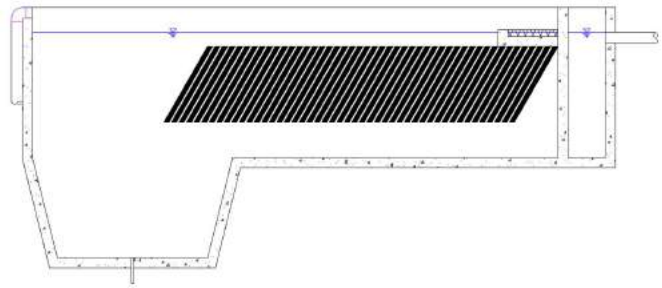
= **0,41 m/s (memenuhi range 0,3 – 0,6 m/s^2)**

- **Resume Bangunan**
  - Panjang saluran pengumpul (L) = 0,75 m
  - Lebar saluran pengumpul (W) = 3,5 m
  - Tinggi saluran pengumpul (H) = 3 m
  - *Freeboard* (Fb) = 0,3 m
  - Tinggi total saluran pengumpul (Htot) = 3,3 m
  - Diameter pipa *outlet* saluran (D) = 0,2 m → 8 inch

- **Sketsa**
  - Tampak denah



  - Tampak potongan



5.5 *Activated Sludge*

- **Kriteria Perencanaan**
  - Umur lumpur = 4 - 10 hari
  - F/M rasio = 0,25 - 0,5 kg BOD/kg MLVSS.d
  - *Hydraulic detention time* (HDT) = 6 - 8 jam

    (Sumber: *Marcos Von Sperling, Activated Sludge and Aerobic Biofilm Reactor*, hal 6)
  - VSS/SS rasio = 0,7 - 0,85

    (Sumber: *Marcos Von Sperling, Activated Sludge and Aerobic Biofilm Reactor*, hal 21)
  - *Particulate* BOD = 0,45 – 0,65 $mgBOD_5/mgTSS$

    (Sumber: *Marcos Von Sperling, Activated Sludge and Aerobic Biofilm Reactor*, hal 29)
  - *Yield Coefficient* (Y) = 0,5 - 0,7 gr VSS/gr BOD_5 *removed Endogenous*
  - *Respiration Coefficient* (Kd) = 0,06 - 0,10 gr VSS/gr VSS.d

    (Sumber: *Marcos Von Sperling, Activated Sludge and Aerobic Biofilm Reactor*, hal 20)
  - Standard *oxygenation efficiency* = 1,8 kg O_2/kW.jam

    (Sumber: *Marcos Von Sperling, Activated Sludge and Aerobic Biofilm Reactor*, hal 66)
  - Ketinggian bak aerasi (H) = 4.5 – 7.5 m

    (Sumber: *Metcalf & Eddy, Waste Water Engineering Treatment & Reuse, 4th Edition,* hal 817)

- Konsentrasi MLVSS (Xv) = 1500 - 3500 mg/L
- Konsentrasi MLSS (X) = 2000 - 4000 mg/L
- Rasio resirkulasi lumpur (Qr/Q) = 0,6 - 1
- *Biodegradable fraction of* VSS (fb) = 0,55 – 0,77
- *Effluent soluble* BOD = 5 – 20 mg/L

  (Sumber: *Marcos Von Sperling, Activated Sludge and Aerobic Biofilm Reactor*, hal 69)
- Kebutuhan O_2 = 0,8 – 0,94 kg O_2/kg BOD removed

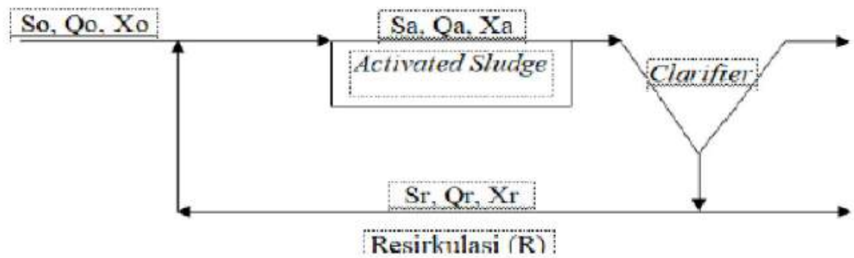
  (Sumber: *Marcos Von Sperling, Activated Sludge and Aerobic Biofilm Reactor*, hal 205)

● **Direncanakan**

- Jumlah unit = 1 unit
- Debit (Q) = 1100 m^3/hari → 0,013 m^3/s
- Umur lumpur = 4 hari
- VSS/SS rasio = 0,8
- Konsentrasi MLVSS (Xv) = 3000 mg VSS/L
- Konsentrasi MLSS (X) = 3500 mg/L
- Y = 0,6 gr VSS/gr BOD_5 removed
- Kd = 0,08 gr VSS/gr VSS.d
- Suhu = 30°
- Rasio Resirkulasi (R) = 0,6
- Standard *oxygenation efficiency* = 1,8 kg O_2/kW.jam
- Biodegradable fraction of VSS (fb) = 0,75
- *Effluent soluble* BOD = 5 mg/L
- Ketinggian bak aerasi (H) = 6 m
- *Freeboard* (fb) = 10 % kedalaman bak (H)
- Bentuk bak AS = *rectangular*
- *Influent* BOD = 765,5 mg/L
- Persentase *removal* BOD = 90 %

- Kebutuhan O_2 = 0,9 kg O_2/kg BOD removed
- Influent COD = 875 mg/L
- Persentase removal COD = 87 %
- Influent NH_3 = 25 mg/L
- Persentase removal NH_3 = 90 %
- Influent fenol total = 13
- Persentase removal fenol total = 99%
- Rasio L : W = 2 : 1

- **Perhitungan**



Keterangan :

Qo = Debit *influent*

Qa = Debit di dalam reaktor

Qr = Debit resirkulasi

So = Konsentrasi organik (BOD *influent*)

Sa = Konsentrasi organik (BOD di dalam reaktor)

Sr = Konsentrasi organik (BOD *effluent*)

Xa = Konsentrasi mikroorganisme dalam reaktor (MLVSS)

Xr = Konsentrasi mikroorganisme pada lumpur yang disirkulasikan (MLSS)

1. Removal Polutan
   - BOD *effluent* = BOD *influent* – (% *removal* x BOD *influent*)
     = 765,5 mg/L – (90 % x 765,5 mg/L)
     = 76,55 mg/L

- COD *effluent* = COD *influent* – (% *removal* x COD *influent*)
  = 875 mg/L – (87 % x 875 mg/L)
  = 113,75 mg/L
- Ammonia (NH3) *effluent* = NH3 *influent* – (% *removal* x NH3 *influent*)
  = 25 mg/L – (99 % x 25 mg/L)
  = 0,25 mg/L

2. Partikulat BOD di *effluent*

   V = (VSS/SS) x fb
   = 0,8 x 0,75
   = 0,6 mg BOD/mg SS

   Maka, untuk *effluent* BOD sebesar 76,55 mg/L (sesuai baku mutu)

   BOD Partikulat = 0,6 x 76,55
   = 45 mg BOD/L

3. Total BOD effluent

   T BOD = BOD terlarut + partikulat BOD
   = 5 mg/L + 45 mg BOD/L
   = 50 mg/L

4. Efisiensi sistem dalam penyisihan BOD

   % E $= \frac{BOD\ influent - BOD\ effluent}{BOD\ influent}\ x\ 100$

   $= \frac{765{,}5\ \frac{mg}{L} - 76{,}55\ mg/L}{765{,}5\ \frac{mg}{L}}\ x\ 100$

   = 90%

5. BOD yang teremoval

   BODr = BOD *influent* (Co) x %*removal*
   = 765,5 mg/L x 90%
   = 688,95 mg/L

6. BOD yang lolos (Cr)

   BODs = BODi – BODr

= 765,5 mg/L – 688,95 mg/L

= 76,55 mg/L

7. Debit resirkulasi

Qr = Qo x R

= 0,013 m^3/s x 0,6

= 0,008 m^3/s

8. Debit yang masuk ke *activated sludge*

Qin = Qo + Qr

= 0,013 m^3/s + 0,008 m^3/s

= 0,021 m^3/s → 1797,12 m^3/hari

9. Volume bak

Qin $= \frac{Y.\theta_c.Q.(S_0 - S)}{X_v(1+f_b.K_d.\theta_c)}$

$= \frac{0,6.4.(1797,12\ m^3/hari).((765,5\ mg/L)-(5\ mg/L))}{3000(1+(0,75).(0,08).4)}$

= 881,75 m^3

10. Dimensi bak

Lebar bak (W) $= \sqrt{\frac{V}{2H}}$

$= \sqrt{\frac{881,75}{2x6}}$

= 8,572 m = 9 m

Panjang bak (L) = 2 x W

= 2 x 9

= 18 m

H_{total} = H + (H x freeboard)

= 6 m + (6 m x 10%)

= 6 m + 0,6 m

= 6,6 m

Cek volume maks = L x W x H total

= 18 m x 9 m x 6,6 m

= 1069,2 m³

11. Konsentrasi resirkulasi lumpur

Xr $= \frac{X(1+R)}{R}$

$= \frac{3500\ mg/L(1+0,6)}{0,6}$

= 9333,3 mg/L

12. Kuantitas lumpur yang dihasilkan setiap hari

Yobs $= \frac{Y}{1+(f_b K_d \theta_c)}$

$= \frac{0,6}{1+(0,75x0,08x4)}$

= 0,484 mg/L

13. Penyisihan beban BOD

Sr = Qo x (So - S)

= (0,013 x 1000 x 86400) x (765,5 - 5)

= 854193600 mg/hari = 854,19 kg/hari

14. Lumpur aktif yang harus dibuang

Pxv = Yobs x Sr

= 0,484 x 854,19

= 413,32 kg VSS/hari

15. Produksi lumpur (Px MLSS)

Px $= \frac{Pxv}{\frac{VSS}{SS}}$

$= \frac{413,32\ kg\ VSS/hari}{0,8}$

= 516,65 kg VSS/hari

16. Debit lumpur yang harus dibuang (Qex)

Jika dibuang melalui bioreaktor

Qex $= \frac{V}{\theta c}$

$= \frac{881,75\ m3}{4\ hari}$

= 220,44 m^3/hari

Jika dibuang melalui resirkulasi

Qex $= \frac{V}{\theta c} \text{ x } \frac{X}{Xr}$

$= \frac{881,75\ m3}{4\ hari} \text{ x } \frac{3500\ mg/L}{9333\ mg/L}$

= 82,66 m^3/hari

17. Kontrol F/M rasio

F/M $= \frac{Qin\ x\ So}{Vol\ x\ Xv}$

$= \frac{1797,12\ m3/hari\ x\ 0,765\ kg/m3}{881,75\ m3\ x\ 3,2\ kg/m3}$

= **0,488 m^3/hari** (memenuhi 0,25 – 0,5)

18. Kebutuhan oksigen total

Keb.oksigen $= \frac{1,46\ x\ Qin\ x\ (Co - C\ )}{10^3}$

$= \frac{1,46\ x\ 1797,12\ x\ (765,5 - 76,55)}{10^3}$

= 1807,66 kg/hari

= 75,32 kg/jam

Berdasarkan kebutuhan oksigen yang dibutuhkan, diperlukan *surface aerator* SAR-325 sebanyak 3 buah untuk memenuhi kebutuhan oksigen dengan kapasitas transfer oksigen tiap aerator sebesar 27,5 kg/jam.

Type	Motor		Surface Aerator				
	Power (hp)	Speed (r/min)	OC-HR (kg/h)	MD (m)	MZ (m)	D (m)	PR (m³/min)
SAR-32	2	1450	3.0	6	12	2~3	5
SAR-33	3	1450	4.2	9	18	3~4	7
SAR-35	5	1450	6.6	12	24	3~4	9
SAR-37	7¹/2	1450	9.6	16	32	3~4	11
SAR-310	10	1450	11.5	19	38	3~4	19
SAR-315	15	1450	16.5	27	54	3~4	24
SAR-320	20	1450	21.0	32	64	3~4	29
SAR-325	25	1450	27.5	36	72	3~4	33
SAR-330	30	1450	31.0	40	80	3~4	37
SAR-340	40	1450	38.0	45	90	5~6	46
SAR-350	50	1450	50	50	100	5~6	55
SAR-360	60	1450	61	56	112	5~6	65
SAR-375	75	1450	73	62.5	125	5~6	80
SAR-3100	100	1450	95	70	140	5~6	120

MZ: Diameter of Mixing Zone. (m)
OC-HR: Kgs Oxygenation Capacity per Hour. (kg/h)
MD: Diameter of Complete Mixing in Meter at minimum average velocity of 1.2 meter per second (approx). (m)
D: Depth in Meter of Complete Mixing, related to MD.
PR: Pumping Rate, m³per Minute.

19. Total kebutuhan *power*

ΣP = n aerator x P

= 3 x 25 hp

= 75 hp

= 55,93 KW

20. Pipa *inlet*

Diameter pipa *inlet* = diameter pipa outlet Ekualisasi

= **0,2 m**

Berdasarkan pipa yang ada di pasaran, didapatkan diameter sebesar **216 mm** atau **8 inch** merk rucika.

KELAS D

Diameter		Tebal Dinding (mm)	Panjang (m)	Sistem Penyambungan	Kode Produk
inch	mm				
1-1/4	42	1,30	4	SC	510042001
1-1/2	48	1,30	4	SC	510048001
2	60	1,30	4	SC	510060001
2-1/2	76	1,40	4	SC	510076001
3	89	1,60	4	SC	510089001
4	114	2,00	4	SC	510114001
5	140	2,60	4	SC	510140001
6	165	3,00	4	SC	510165001
8	216	4,20	4	SC	510216001
10	267	5,20	4	SC	510267001
12	318	6,20	4	SC	510318001

SC : Solvent Cement (Penyambungan dengan Lem)

21. Pipa outlet menuju clarifier

Direncanakan :

- v = 0,4 m/s
- Qout = Qin
  = 0,021

○ Luas Penampang Pipa

A $= \frac{Q}{V}$

$= \frac{0,021\ m3/s}{0,5\ m/s}$

= 0,0416 m²

○ Diameter Pipa Outlet

D $= \sqrt{\frac{4.A}{\pi}}$

$= \sqrt{\frac{4.0,0416\ m2}{3,14}}$

= 0,23 m

Berdasarkan pipa yang ada dipasaran, didapatkan diameter sebesar **267 mm** atau **10 inch** merk rucika.

KELAS D

Diameter		Tebal Dinding (mm)	Panjang (m)	Sistem Penyambungan	Kode Produk
inch	mm				
1-1/4	42	1,30	4	SC	510042001
1-1/2	48	1,30	4	SC	510048001
2	60	1,30	4	SC	510060001
2-1/2	76	1,40	4	SC	510076001
3	89	1,60	4	SC	510089001
4	114	2,00	4	SC	510114001
5	140	2,60	4	SC	510140001
6	165	3,00	4	SC	510165001
8	216	4,20	4	SC	510216001
10	267	5,20	4	SC	510267001
12	318	6,20	4	SC	510318001

SC : Solvent Cement (Penyambungan dengan Lem)

22. Cek kecepatan aliran (v cek)

v cek $= \frac{Q}{A}$

$= \frac{Q}{\frac{1}{4} x\ \pi\ x\ D^2}$

$= \frac{0{,}021\ m3/s}{\frac{1}{4} x\ 3{,}14\ x\ 0{,}267^2\ m}$

= 0,41 m/s

Perhitungan Pompa AS menuju Clarifier

- **Kriteria Perencanaan**
  - K Elbow 90^0 = 0,9

    (*Sumber: Dake, J.M.K., Endang P. Tachyan dan Y.P. Pangaribuan, 1985. "Hidrolika Teknik* Edisi II", Erlangga. Jakarta)
  - K reducer = 0,25

    (*Sumber: Practical Hydrolics For The Public Work Engineer, 1968*)

- **Data perencanaan**
  - Elbow 90^0 discharge = 3 buah
  - Increaser suction = 1 buah
  - Increaser discharge = 1 buah
  - Q bak = 0,021 m3/s → 1123,2 m^3/hari
  - L suction = 1 m

- L discharge = 16 m
- Diameter pipa = 0,27 m → 10 inch
- Kecepatan pipa (v) = 0,41 m/s
- Head statis = 0,57 m

- **Perhitungan**

1. Perhitungan suction

   Headloss mayor

   Hf $= \frac{10.7 \ x \ L \ x \ Q^{1.85}}{C^{1.85} \ x \ D^{4.87}}$

   $= \frac{10.7 \ x \ 1 \ m \ x \ (0.021 \ m3/detik)^{1.85}}{130^{1.85} \ x \ 0.27 \ m^{4.87}}$

   = 0,0006 m

   Headloss minor (reducer)

   $Hf_{reducer} = n \ x \ k \ x \ \frac{v^2}{2g}$

   $Hf_{reducer} = (1 \ x \ 0.25 \ x \ \frac{0.41 \ m/s^2}{2 \ x \ 9.81 \ m/s2})$

   = 0,0021 m

   ∑Hf minor

   Hf_{minor} = Hf minor reducer

   = 0,0021 m

   ∑Hf suction

   Hfs = Hf mayor + Hf minor

   = 0,0006 m + 0,0021 m

   = 0,0028 m

2. Perhitungan Discharge

   Headloss mayor

   Hf $= \frac{10.7 \ x \ L \ x \ Q^{1.85}}{C^{1.85} \ x \ D^{4.87}}$

   $= \frac{10.7 \ x \ 16 \ m \ x \ (0.021 \ m3/detik)^{1.85}}{130^{1.85} \ x \ 0.27 \ m^{4.87}}$

   = 0,0097 m

   Headloss minor (elbow)

Hf_{elbow} $= n \times k \times \frac{v^2}{2g}$

Hf_{elbow} $= (3 \times 0.9 \times \frac{0.41\ m/s^2}{2 \times 9.81\ m/s2})$

= 0,0231 m

Headloss minor (reducer)

$Hf_{reducer}$ $= n \times k \times \frac{v^2}{2g}$

$Hf_{reducer}$ $= (1 \times 0.25 \times \frac{0.41\ m/s^2}{2 \times 9.81\ m/s2})$

= 0,0021 m

∑Hf minor

Hf_{minor} = Hf minor elbow + Hf minor reducer

= 0,0231 m + 0,0021 m

= 0,0253 m

∑Hf discharge

Hfd = Hf mayor + Hf minor

= 0.0097 m + 0.0253 m

= 0.035 m

3. Perhitungan Head total

Head total = head statis + ∑Hf suction + ∑Hf discharge

= 0,57 m + 0.0028 m + 0.035

= 0,61 m

4. Perhitungan Head pompa

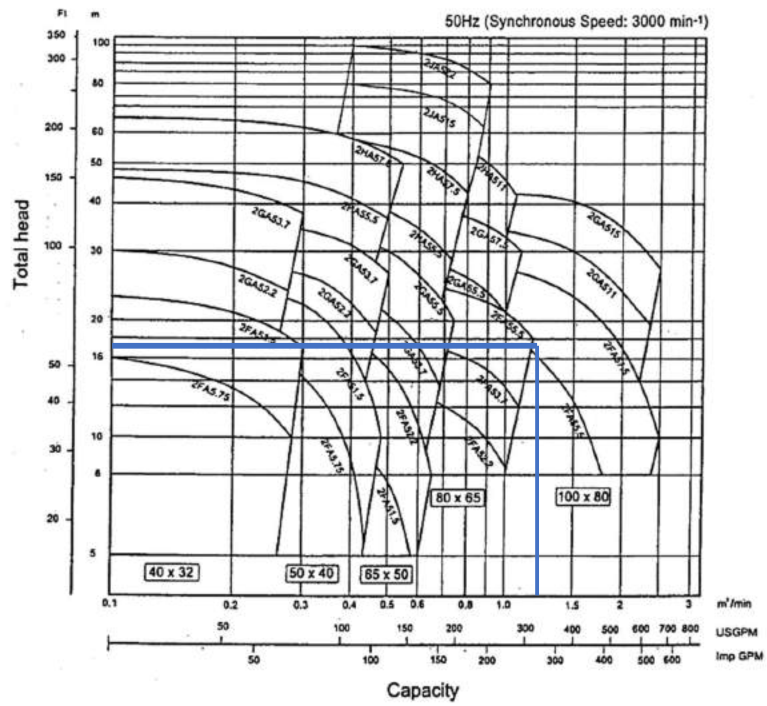
Head pompa = Head statis + L suction + L discharge

= 0,57 m + 1 m + 16 m

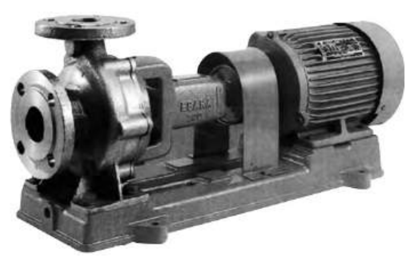
= 17,56 m

Head pompa > Head total

17,56 m > 0,61 m (memenuhi persyaratan)

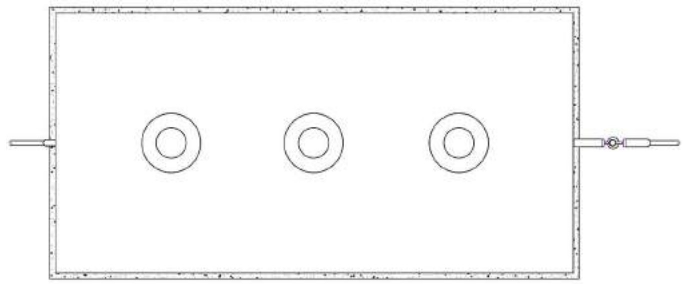


Berdasarkan grafik di atas, maka dipilih pompa dengan merek Ebara dengan tipe 100 x 80 FSSFA57,5 dengan spesifikasi yang tertera pada lampiran A.

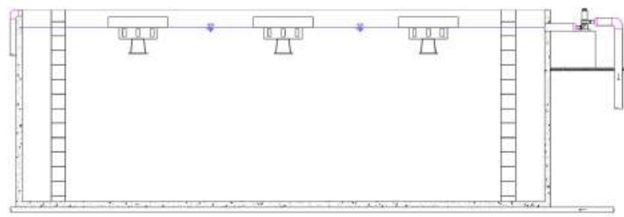


- **Resume**
  - Panjang bak (L) = 18 m
  - Lebar bak (W) = 9 m
  - Tinggi total (H_{total}) = 6,6 m
  - Diameter Pipa *inlet* = 10 inch
  - Diameter Pipa *outlet* = 10 inch
  - *Surface aerator* (n) = 3 buah

- **Sketsa**
  - Tampak denah



  - Tampak potongan



5.5 *Clarifier*

- **Kriteria Perencanaan**
  - Bentuk bak pengendap = *Circular*
  - Kedalaman (H) = 3 – 4,9 m
  - Diameter = 3 – 60 m
  - *Bottom slope* = 1/16 – 1/6 mm/mm
  - *Flight speed = 0,02 – 0,05 m/menit*
  - Waktu detensi (td) = 1,5 – 2,5 jam
  - *Over flow rate*

    Average = 30 – 50 m^3/m^2.hari

    Peak = 80 – 120 m^3/m^2.hari
  - *Weir loading* = 125 – 500 m^3/m^2.hari

    (Sumber : Metcalf & Eddy, Wastewater Engineering Treatment & Reuse, Fourth Edition, hal 398)
  - Diameter inlet well = 15% - 20% diameter bak
  - Ketinggian inlet well = 0,5 – 0,7 m
  - Kecepatan inlet well = 0,3 – 0,75 m/s

(Sumber : Metcalf & Eddy, Wastewater Engineering Treatment & Reuse, Fourth Edition, hal 401)

- Konsentrasi solid = 4% - 12%

  (Sumber : Metcalf & Eddy, Wastewater Engineering Treatment & Reuse, Fourth Edition, hal 411)
- % Removal TSS = 60% - 80%

  (Sumber : Huisman, hal 12)
- *Specific gravity sludge (Sg)* = 1,005
- *Specific gravity solid (Ss)* = 1,25

  (Sumber : Metcalf & Eddy, Wastewater Engineering Treatment & Reuse, Fourth Edition, hal 1456)
- Massa jenis air (ρ), T (30ºC) = 0,99568 g/cm³ = 9,957 kg/L
- Viskositas kinematic (v) = 0,8039 x 10^{-6} m²/s
- Viskositas dinamik (μ) = 0,8004 x 10^{-3} N s/m²

  (Sumber : Reynolds, Tom D. dan Paul A. Richards. 1996. Unit Operations and Processes in Environmental Engineering 2nd edition, hal 762)
- Bilangan Reynold (NRe) untuk Vs = < 1 (laminer)

  (Sumber : Reynolds, Tom D. dan Paul A. Richards. 1996. Unit Operations and Processes in Environmental Engineering 2nd edition, hal 224)
- Bilangan Reynold (NRe) untuk Vh = < 2000 (aliran laminer)
- Bilangan Froude (Nfr) = > 10^5

  (Sumber : SNI 6774:2008 Tata Cara Perencanaan Unit Paket Instalasi Pengolahan Air, hal 6)

● **Data Perencanaan**

- Menggunakan 1 bak pengendap berbentuk *circular*
- Debit air limbah (Q) = 1100m³/hari = 0,013 m³/s
- Waktu detensi = 2 jam = 7200 detik
- Kedalaman bak = 3,5 m

- Massa jenis air (ρ), T (30ºC) = 0,99568 g/cm³ = 9,957 kg/L = 996 kg/m³
- Viskositas kinematik (v) = 0,8039 x 10^{-6} m²/s
- Viskositas dinamik (μ) = 0,8004 x 10^{-3} N s/m²
- Koef. manning = 0,013
- *Over flow rate* = 40 m³/m².hari
- Diameter inlet well (D') = 20% diameter bak
- Ketinggian inlet well = 0,7 m
- Kons. MLSS = 3500 mg/L
- Kons MLVSS = 3000 mg/L
- MLVSS (P x v) = 413,32 kg VSS/hari
- Qr = 0,008 m³/s → dari *activated sludge*
- % Removal TSS = 80%
- Waktu pengurasan = 3 hari
- Menggunakan V notch dengan kemiringan 45º
- Jarak antar V notch = 50 cm
- Percepatan gravitasi = 9,81 m/s²
- Massa jenis sludge = Sg x ρ = 1,005 x 996 kg/m³ = 1000,98 kg/m³

- **Perhitungan**

Zona *Settling*

1. Qin pada *clarifier*

   Qin = Qo + Qr

   Qin = 0,013 m³/s + 0,008 m³/s

   Qin = 0,021 m³/s = 1797,12 m³/hari

2. Luas surface area (A)

   A $= \frac{Qin}{OFR}$

   A $= \frac{1797{,}12\ m^2/hari}{40\ m^3/m^2.hari}$

   A = 44,93 m²

3. Diameter (D)

D $= \sqrt{\frac{4.A}{\pi}}$

D $= \sqrt{\frac{4\ x\ 44{,}928}{3{,}14}}$

D = 7,57 m → 7,5 m (memenuhi syarat 3 - 60 m)

r $= \frac{D}{2}$

r $= \frac{7{,}5\ m}{2}$

r = 3,75 m

4. Luas Surface area baru

A $= \frac{1}{4}$ x π x D^2

A $= \frac{1}{4}$ x 3,14 x $7{,}5^2$ m

A = 44,16 m²

5. Cek *Overflow Rate*

OFR $= \frac{Qin}{A}$

OFR $= \frac{1797{,}12\ m^3/hari}{44{,}16\ m^2}$

OFR = 40,70 m^3/m^2hari (memenuhi syarat 30 – 50 m^3/m^2hari)

6. Volume bak

V = A x H

V = 44,16 m^2 x 3,5 m

V = 154,55 m³

7. Cek waktu detensi (td)

td $= \frac{V}{Qin}$

td $= \frac{154{,}55\ m^3}{0{,}021\ m^3/s}$

td = 7430,14 s → 2,06 jam (memenuhi syarat 1,5 – 2,5 jam)

8. Kecepatan pengendapan partikel (Vs)

Vs $= \frac{H}{td}$

Vs $= \frac{3{,}5\ m}{7430{,}14\ s}$

Vs = 0,00047 m/s

9. Diameter partikel (Dp)

Dp $= \sqrt{\frac{Vs.18.v}{g\ (Ss-1)}}$

Dp $= \sqrt{\frac{0{,}00047\ \frac{m}{s}\ x\ 18\ x\ (0{,}8039\ x\ 10^{-6}\ \frac{m^2}{s})}{9{,}81\ \frac{m}{s^2}\ (1{,}25-1)}}$

Dp = 5,27 x 10^{-5} m

10. Cek bilangan N_{Re} Vs

N_{Re} $= \frac{\rho_s D_p v_s}{\mu}$

N_{Re} $= \frac{1000{,}98\ \frac{kg}{m^3}\ x\ (5{,}27\ x\ 10^{-5}\ m)\ x\ 0{,}00047\ m/s}{0{,}8004\ x\ 10^{-3}\ N\ s/m^2}$

N_{Re} = 0,031 (memenuhi syarat N_{Re} < 1)

11. Kecepatan horizontal di bak (Vh)

Vh $= \frac{Qin}{\pi\ x\ D\ x\ H}$

Vh $= \frac{0{,}021\ \frac{m^3}{s}}{3{,}14\ x\ 7{,}5\ m\ x\ 3{,}5\ m}$

Vh = 0,0003 m/s

12. Jari-jari hidrolis (R)

R $= \frac{r\ x\ H}{r+2H}$

R $= \frac{3{,}75\ m\ x\ 3{,}5\ m}{3{,}75\ m + (2\ x\ 3{,}5\ m)}$

R = 1,22 m

13. Cek bilangan N_{Re}

N_{Re} $= \frac{Vh\ x\ r}{v}$

N_{Re} $= \frac{0{,}0003\ \frac{m}{s}\ x\ 3{,}75\ m}{0{,}8039\ x\ 10^{-6}\ m^2/s}$

N_{Re} = 1177,15 (memenuhi syarat < 2000)

14. Cek bilangan Froude (N_{fr})

N_{fr} $= \frac{Vh}{\sqrt{g.H}}$

N_{fr} $= \frac{0{,}0003\ m/s}{\sqrt{9{,}81\ x\ 3{,}5\ m}}$

N_{fr} = 4,31 x 10^{-5} (memenuhi syarat N_{fr} > 10^{-5})

15. Cek kecepatan Penggerusan/*scouring* (Vs)

K = konstanta kohesi untuk partikel yang saling mengikat 0,06

F = faktor friksi Darcy-Weisbach antara 0,02-0,03

Vs > Vh

Vs = $\sqrt{\frac{8k(S-1).g.Dp}{f}}$

Vs = $\sqrt{\frac{8\ x\ 0{,}06\ (1{,}25-1)\ 9.81\ x\ (5.27\ x\ 10^{-5}\ m)}{0{,}03}}$

Vs = 0,045 m/s (memenuhi syarat Vs > Vh)

Zona Inlet

1. Diameter *inlet wall* (D')

D' = 20% x diameter bak

D' = 20% x 7,5 m

D' = 1,5 m

2. Kecepatan air di *inlet wall*

v = $\frac{Qin}{A}$

v = $\frac{0{,}021\ m^3/s}{\frac{1}{4}\ x\ \pi\ x\ D'^2}$

v = $\frac{0{,}021\ m^3/s}{\frac{1}{4}\ x\ 3{,}14\ x\ (1{,}5\ m)^2}$

v = 0,012 m/s

3. Pipa *inlet*

- Luas penampang pipa

A = $\frac{Qin}{V}$

A = $\frac{0{,}021}{0{,}5\ m/s}$

A = 0,0416 m2

- Diameter pipa *inlet*

D = $\sqrt{\frac{4.A}{\pi}}$

D = $\sqrt{\frac{4\ x\ 0{,}416}{3{,}14}}$

D = 0,23 m = 230 mm

Berdasarkan pipa yang ada di pasaran, didapatkan diameter sebesar **267 mm** atau **10 inch** merek rucika.

KELAS D

Diameter		Tebal Dinding (mm)	Panjang (m)	Sistem Penyambungan	Kode Produk
inch	mm				
1-1/4	42	1,30	4	SC	510042001
1-1/2	48	1,30	4	SC	510048001
2	60	1,30	4	SC	510060001
2-1/2	76	1,40	4	SC	510076001
3	89	1,60	4	SC	510089001
4	114	2,00	4	SC	510114001
5	140	2,60	4	SC	510140001
6	165	3,00	4	SC	510165001
8	216	4,20	4	SC	510216001
10	267	5,20	4	SC	510267001
12	318	6,20	4	SC	510318001

SC : Solvent Cement (Penyambungan dengan Lem)

- Cek kecepatan pipa *inlet*

v $= \frac{Qin}{A}$

v $= \frac{0{,}021\ m^3/s}{\frac{1}{4}\ x\ \pi\ x\ D^2}$

v $= \frac{0{,}021\ m^3/s}{\frac{1}{4}\ x\ 3{,}14\ x\ (0{,}267\ m)^2}$

v = 0,41 m/s (memenuhi)

Zona *Thickening*

1. MLVSS dalam clarifier

Diasumsikan %*biological* yang tetap dalam bak *activated sludge* = 30%

maka :

$MLVSS_{AS}$ = 30% x $MLVSS_{total}$

= 30% x 3000 mg/L

= **900 mg/L**

Sehingga MLVSS pada clarifier adalah sebesar :

$MLVSS_{Clarifier}$ = $MLVSS_{total}$ – $MLVSS_{AS}$

= 3000 mg/L – 900 mg/L

= 2100 mg/L

2. Massa Solid Total pada clarifier

$M_{solid\ total}$ = $MLVSS_{Clarifier}$ x $V_{Clarifier}$

= 2100 mg/L x 154,55 m^3

= 2100 g/m^3 x 154,55 m^3

= 324548,4 g

= 324,55 kg

3. Kedalaman zona thickening

H = $\frac{M\ solid\ total}{X\ x\ A}$

= $\frac{324548{,}4\ g}{3500\ \frac{g}{m^3}\ x\ 44{,}93\ m^2}$

= 2,41 m

Zona *Sludge*

❖ **Produksi Lumpur yang dibuang menuju SDB**

1. *Removal* TSS

Cn = Co – (Co x (100% - % *Removal* TSS)

Cn = 249,6 mg/L – (249,6 mg/L x (100% - 80%)

Cn = 249,6 mg/L – 49,92 mg/L

Cn = 199,68 mg/L

2. Berat *solid*

Berat solid = (*Removal* TSS x Q*o*) + P x MLSS

= (199,68 mg/L x 13 L/s) + 413,32 kg VSS/hari

= 627,6 kg/hari

3. Berat jenis *solid*

Berat jenis *solid* = Ss x massa jenis air

= 1,25 x 995,7 kg/m^3

= **1244,63 kg/m^3**

4. Volume *solid*

Volume *solid* = $\frac{berat\ solid}{berat\ jenis\ solid}$

= $\frac{627{,}6\ kg/hari}{1244{,}63\ kg/m^3}$

= **0,51 m^3**

5. Berat air

Berat air = $\frac{95\%}{5\%}$ x berat *solid*

$= \frac{95\%}{5\%}$ x 627,6 kg/hari

= 12114,4 kg/hari

6. Volume air

Volume air $= \frac{berat\ air}{berat\ jenis\ air}$

$= \frac{12114{,}4\ kg/hari}{995{,}7\ kg/m^3}$

= 12,17 m³

7. Volume *sludge*

Volume *sludge* = volume solid + volume air

= 0,51 m³ + 12,17 m³

= 12,68 m³

8. Berat jenis *sludge*

Berat jenis *sludge* = *spesific gravity of sludge* (Sg) x massa jenis air

= 1,005 x 995,7 kg/ m3

= 1000,98 kg/m3

9. Berat *sludge*

Berat *sludge* = volume *sludge* x berat jenis *sludge*

= 12,68 m³ x 1000,98 kg/m3

= 12691,43 kg/hari

10. Debit *sludge* $= \frac{berat\ sludge}{berat\ jenis\ sludge}$

$= \frac{12691{,}43\ kg/hari}{1000{,}98\ kg/m3}$

= 12,68 m^3/hari → 1,47 x 10^{-4} m^3/s

❖ **Lumpur resirkulasi**

1. *Removal* TSS

Cn = Co – (Co x (100% - % *Removal* TSS)

Cn = 249,6 mg/L – (249,6 mg/L x (100% - 80%)

Cn = 249,6 mg/L – 49,92 mg/L

Cn = 199,68 mg/L

2. Berat *solid*

Berat solid = (*Removal* TSS x Q*r*) + P x MLSS

= (199,68 mg/L x 7,8 L/s) + 103,33 kg VSS/hari

= 237,9 kg/hari

3. Berat jenis *solid*

Berat jenis *solid* = Ss x massa jenis air

= 1,25 x 995,7 kg/m³

= **1244,63 kg/m³**

4. Volume *solid*

Volume *solid* $= \frac{berat\ solid}{berat\ jenis\ solid}$

$= \frac{237{,}9\ kg/hari}{1244{,}63\ kg/m^3}$

= **0,19 m³**

5. Berat air

Berat air $= \frac{95\%}{5\%}$ x berat *solid*

$= \frac{95\%}{5\%}$ x 237,3 kg/hari

= 4520,07 kg/hari

6. Volume air

Volume air $= \frac{berat\ air}{berat\ jenis\ air}$

$= \frac{4520{,}07\ kg/hari}{995{,}7\ kg/m^3}$

= 4,54 m³

7. Volume *sludge*

Volume *sludge* = volume solid + volume air

= 0,19 m³ + 4,54 m³

= 4,73 m³

8. Berat jenis *sludge*

Berat jenis *sludge* = *spesific gravity of sludge* (Sg) x massa jenis air

= 1,005 x 995,7 kg/ m3

= 1000,98 kg/m3

9. Berat *sludge*

Berat *sludge* = volume *sludge* x berat jenis *sludge*

= 4,73 m^3/hari x 1000,98 kg/m3

= 4735,36 kg/hari

10. Debit *sludge* = $\frac{berat\ sludge}{berat\ jenis\ sludge}$

= $\frac{4735{,}36\ kg/har}{1000{,}98\ kg/m3}$

= 4,73 m^3/hari → 5,5 x 10^{-5}

❖ **Produksi Lumpur Total**

1. *Removal* TSS

Cn = Co – (Co x (100% - % *Removal* TSS)

Cn = 249,6 mg/L – (249,6 mg/L x (100% - 80%)

Cn = 249,6 mg/L – 49,92 mg/L

Cn = 199,68 mg/L

2. Berat *solid*

Berat solid = (*Removal* TSS x Q*in*) + P x MLSS

= (199,68 mg/L x 20,8 L/s) + 516,65 kg VSS/hari

= 875,5 kg/hari

3. Berat jenis *solid*

Berat jenis *solid* = Ss x massa jenis air

= 1,25 x 995,7 kg/m^3

= **1244,63 kg/m^3**

4. Volume *solid*

Volume *solid* = $\frac{berat\ solid}{berat\ jenis\ solid}$

= $\frac{875{,}5\ kg/hari}{1245\ kg/m^3}$

= **0,7 m^3**

5. Berat air

Berat air = $\frac{95\%}{5\%}$ x berat *solid*

= $\frac{95\%}{5\%}$ x 875,5 kg/hari

= 16634,47 kg/hari

6. Volume air

   Volume air = $\frac{berat\ air}{berat\ jenis\ air}$

   = $\frac{16634\ kg/hari}{995{,}7\ kg/m^3}$

   = 16,71 m³

7. Volume *sludge*

   Volume *sludge* = volume solid + volume air

   = 0,7 m³ + 16,71 m³

   = 17,41 m³

8. Berat jenis *sludge*

   Berat jenis *sludge* = *spesific gravity of sludge* (Sg) x massa jenis air

   = 1,005 x 995,7 kg/ m3

   = 1000,98 kg/m3

9. Berat *sludge*

   Berat *sludge* = volume *sludge* x berat jenis *sludge*

   = 17,41 m³/hari x 1000,98 kg/m3

   = 17421,79 kg/hari

10. Debit *sludge* = $\frac{berat\ sludge}{berat\ jenis\ sludge}$

   = $\frac{17421{,}79\ kg/hari}{1000{,}98\ kg/m3}$

   = 17,41 m^3/hari

11. Dimensi ruang lumpur (*sludge*)

   Volume lumpur = 17,4 m³

   Asumsi waktu pengurasan = 1 hari

   Jari-jari permukaan bawah = 2 m (asumsi)

   - Tinggi ruang lumpur (H)

     V *sludge* = Volume kerucut

     17,4 m³ = $\frac{1}{3}$x π x H x (R² + r² + R x r)

     17,4 m³ = $\frac{1}{3}$ x 3,14 x H x (1,22² + 3,75² +(1,22 x 3,75))

H = 0,7 m

Zona Outlet

Direncanakan:

- Menggunakan V notch dengan sudut 45^o
- Jarak antar V notch = 50 cm = 0,5 m
- Cd = 0,6
- Q bak effluent = 0,013 m3/s

Perhitungan:

1. Panjang pelimpah (*weir*)

   L = π x D bak

   = 3,14 x 7,5

   = 23,55 m

2. Jumlah V notch

   n $= \frac{L\ weir}{Jarak\ antar\ weir}$

   $= \frac{23{,}55\ m}{0{,}5\ m}$

   = 47 notch

3. Debit melalui V notch

   Q $= \frac{Q}{n}$

   $= \frac{0{,}013\ m3/s}{47}$

   = 0,00028 m^3/s

4. Tinggi limpasan melalui V notch

   Q $= \frac{8}{15}$ x Cd x $\sqrt{2\ x\ g}$ x $\tan\theta$ x $H^{\frac{5}{2}}$

   H $= \sqrt[5]{\frac{Q}{\frac{8}{15}\ x\ Cd\ x\ \sqrt{2\ x\ g}\ x\ tan\theta}^{2}}$

   $= \sqrt[5]{\frac{0{,}013\ m3/s}{\frac{8}{15}\ x\ 0{,}6\ x\ \sqrt{2\ x\ 9{,}81}\ x\ tan45}^{2}}$

   = 0,14 m = 14 cm

5. Saluran Pelimpah

Direncanakan:

- Kecepatan aliran = 0,3 m/s
- Debit = 0,013 m3/s
- Rasio W : H = 1:1

Perhitungan:

a. Luas permukaan saluran pelimpah (A)

A $= \frac{Q}{v}$

$= \frac{0{,}013\ m3/s}{0{,}4\ m/s}$

= 0,03 m²

b. Dimensi saluran pelimpah W : H = 2 : 1

A = W x H

= W x 2W

= $2W^2$

H $= \sqrt{2\ x\ A}$

$= \sqrt{2\ x\ 0{,}04\ m2}$

= 0,15 m

W = 2 x H

= 2 x 0,15

= 0,30 m

Fb = 20% x H

= 20% x 0,15 m

= 0,03 m

H tot = H + Fb

= 0,15 m + 0,03 m

= 0,18 m

6. Pipa outlet

Direncanakan :

- v = 0,6 m/s
- Q = 0,013 m^3/s

- Luas Penampang Pipa

$A = \frac{Q}{V}$

$= \frac{0{,}013\ m3/s}{0{,}6\ m/s}$

= 0,0260 m²

- Diameter Pipa Outlet

$D = \sqrt{\frac{4.A}{\pi}}$

$= \sqrt{\frac{4.0{,}0260\ m2}{3{,}14}}$

= 0,182 m → 182 mm

Berdasarkan pipa yang ada di pasaran, didapatkan diameter sebesar **216 mm** atau **8 inch** merek rucika.

KELAS D

Diameter		Tebal Dinding (mm)	Panjang (m)	Sistem Penyambungan	Kode Produk
inch	mm				
1-1/4	42	1,30	4	SC	510042001
1-1/2	48	1,30	4	SC	510048001
2	60	1,30	4	SC	510060001
2-1/2	76	1,40	4	SC	510076001
3	89	1,60	4	SC	510089001
4	114	2,00	4	SC	510114001
5	140	2,60	4	SC	510140001
6	165	3,00	4	SC	510165001
8	216	4,20	4	SC	510216001
10	267	5,20	4	SC	510267001
12	318	6,20	4	SC	510318001

SC : Solvent Cement (Penyambungan dengan Lem)

- Cek kecepatan pipa outlet

$v = \frac{Q}{A}$

$= \frac{0{,}013\ m^3/s}{\frac{1}{4}\, x\ \pi\ x\ D^2}$

$= \frac{0{,}013\ m^3/s}{\frac{1}{4}\, x\ 3{,}14\ x\ (0{,}216\ m)^2}$

= 0,4 m/s (memenuhi)

7. Pipa *sludge* total

Direncanakan :

- v = 0,5 m/s
- Q = 0,021 m^3/s

- Luas Penampang Pipa

A $= \frac{Q}{V}$

$= \frac{0{,}021\ m3/s}{0{,}5\ m/s}$

= 0,0416 m²

- Diameter Pipa *sludge* total

D $= \sqrt{\frac{4.A}{\pi}}$

$= \sqrt{\frac{4.0{,}0416\ m2}{3{,}14}}$

= 0,230 m → 230 mm

Berdasarkan pipa yang ada di pasaran, didapatkan diameter sebesar 267 **mm** atau **10 inch** merek rucika.

KELAS D

Diameter		Tebal Dinding (mm)	Panjang (m)	Sistem Penyambungan	Kode Produk
inch	mm				
1-1/4	42	1,30	4	SC	510042001
1-1/2	48	1,30	4	SC	510048001
2	60	1,30	4	SC	510060001
2-1/2	76	1,40	4	SC	510076001
3	89	1,60	4	SC	510089001
4	114	2,00	4	SC	510114001
5	140	2,60	4	SC	510140001
6	165	3,00	4	SC	510165001
8	216	4,20	4	SC	510216001
10	267	5,20	4	SC	510267001
12	318	6,20	4	SC	510318001

SC : Solvent Cement (Penyambungan dengan Lem)

- Cek kecepatan pipa outlet

v $= \frac{Q}{A}$

$= \frac{0{,}021\ m^3/s}{\frac{1}{4}\ x\ \pi\ x\ D^2}$

$= \frac{0{,}021\ m^3/s}{\frac{1}{4}\ x\ 3{,}14\ x\ (0{,}267\ m)^2}$

= 0,41 m/s (memenuhi)

8. Pipa resirkulasi

   Direncanakan :

   - v = 0,5 m/s
   - Qr = 0,008 m^3/s

- Luas Penampang Pipa

$A \quad = \frac{Q}{V}$

$= \frac{0{,}008\ m3/s}{0{,}5\ m/s}$

= 0,0156 m²

- Diameter Pipa resirkulasi

$D \quad = \sqrt{\frac{4.A}{\pi}}$

$= \sqrt{\frac{4.0{,}0156\ m2}{3{,}14}}$

= 0,141 m → 141mm

Berdasarkan pipa yang ada di pasaran, didapatkan diameter sebesar **165 mm** atau **6 inch** merek rucika.

KELAS D

Diameter		Tebal Dinding (mm)	Panjang (m)	Sistem Penyambungan	Kode Produk
inch	mm				
1-1/4	42	1,30	4	SC	510042001
1-1/2	48	1,30	4	SC	510048001
2	60	1,30	4	SC	510060001
2-1/2	76	1,40	4	SC	510076001
3	89	1,60	4	SC	510089001
4	114	2,00	4	SC	510114001
5	140	2,60	4	SC	510140001
6	165	3,00	4	SC	510165001
8	216	4,20	4	SC	510216001
10	267	5,20	4	SC	510267001
12	318	6,20	4	SC	510318001

SC : Solvent Cement (Penyambungan dengan Lem)

- Cek kecepatan pipa outlet

$v \quad = \frac{Q}{A}$

$= \frac{Q}{\frac{1}{4} \times \pi \times D^2}$

$= \frac{0{,}008\ m^3/s}{\frac{1}{4}\ x\ 3{,}14\ x\ (0{,}216\ m)^2}$

= 0,43 m/s (memenuhi)

9. Pipa *sludge* menuju SDB

Direncanakan :

- v = 0,5 m/s
- Q = 0,000147 m^3/s

- Luas Penampang Pipa

$A \quad = \frac{Q}{V}$

$= \frac{0{,}000147\ m3/s}{0{,}5\ m/s}$

$=$ **0,0003 m²**

- Diameter Pipa

D $= \sqrt{\frac{4.A}{\pi}}$

$= \sqrt{\frac{4.0{,}0003\ m2}{3{,}14}}$

= 0,0193 m → 19,3 mm → 0,76 inch

Berdasarkan pipa yang ada di pasaran, didapatkan diameter sebesar **0,191 m** atau **0,75 inch**

- Cek kecepatan pipa outlet

v $= \frac{Q}{A}$

$= \frac{Q}{\frac{1}{4}\ x\ \pi\ x\ D^2}$

$= \frac{0{,}000147\ m^3/s}{\frac{1}{4}\ x\ 3{,}14\ x\ (0{,}216\ m)^2}$

= 0,51 m/s (memenuhi persyaratan 0,3 – 0,6 m/s)

Perhitungan Pompa Resirkulasi

- **Kriteria Perencanaan**
  - K Elbow 90^0 = 0,9
  - K Tee = 1,25

  (*Sumber: Dake, J.M.K., Endang P. Tachyan dan Y.P. Pangaribuan, 1985. "Hidrolika Teknik* Edisi II", Erlangga. Jakarta)
  - K increaser = 0,25
  - K check valve = 2,0

  (*Sumber: Practical Hydrolics For The Public Work Engineer, 1968*)

- **Data perencanaan**
  - Elbow 90^0 suction = 2 buah
  - Increaser suction = 1 buah

- Increaser discharge = 1 buah
- Check valve = 1 buah
- Tee = 1 buah
- Q bak = 0,008 m^3/s → 28,80 m^3/jam
- L suction = 34,85 m
- L discharge = 2,63 m
- Diameter pipa = 0,165 m → 6 inch
- Kecepatan pipa (v) = 0,43 m/s
- Head statis = 4,64 m

- **Perhitungan**

1. Perhitungan suction

   Headloss mayor

   Hf $= \frac{10.7 \ x \ L \ x \ Q^{1.85}}{C^{1.85} \ x \ D^{4.87}}$

   $= \frac{10.7 \ x \ 34{,}85 \ m \ x \ (0.008 \ m3/detik)^{1.85}}{130^{1.85} \ x \ 0.165 \ m^{4.87}}$

   = 0,0391 m

   Headloss minor (elbow 90^0)

   Hf_{elbow} $= n \ x \ k \ x \ \frac{v^2}{2g}$

   Hf_{elbow} $= (2 \ x \ 0.9 \ x \ \frac{0.43 \ m/s^2}{2 \ x \ 9.81 \ m/s2})$

   = 0,017 m

   Headloss minor (increaser)

   $Hf_{increaser}$ $= n \ x \ k \ x \ \frac{v^2}{2g}$

   $Hf_{increaser}$ $= (1 \ x \ 0.25 \ x \ \frac{0.43 \ m/s^2}{2 \ x \ 9.81 \ m/s2})$

   = 0,0024 m

   Headloss minor (Tee)

   Hf_{tee} $= n \ x \ k \ x \ \frac{v^2}{2g}$

   Hf_{tee} $= (1 \ x \ 1{,}25 \ x \ \frac{0.43 \ m/s^2}{2 \ x \ 9.81 \ m/s2})$

$= \mathbf{0{,}0118\ m}$

∑Hf minor

Hf_{minor} = Hf minor elbow 90^0 + Hf minor increaser + Hf minor tee

= 0,017 m + 0,0024 m + 0,0118 m

$= \mathbf{0{,}0311\ m}$

∑Hf suction

Hfs = Hf mayor + Hf minor

= 0,0391 m + 0,0311 m

$= \mathbf{0{,}07\ m}$

2. Perhitungan Discharge

Headloss mayor

$$Hf = \frac{10.7\ x\ L\ x\ Q^{1.85}}{C^{1.85}\ x\ D^{4.87}}$$

$$= \frac{10.7\ x\ 2{,}63\ m\ x\ (0.008\ m3/detik)^{1.85}}{130^{1.85}\ x\ 0.165\ m^{4.87}}$$

$= \mathbf{0{,}003\ m}$

Headloss minor (Check valve)

$$Hf_{cvalve} = n\ x\ k\ x\ \frac{v^2}{2g}$$

$$Hf_{cvalve} = (1\ x\ 2{,}0\ x\ \frac{0.43\ m/s^2}{2\ x\ 9.81\ m/s2})$$

$= \mathbf{0{,}0188\ m}$

Headloss minor (increaser)

$$Hf_{increaser} = n\ x\ k\ x\ \frac{v^2}{2g}$$

$$Hf_{increaser} = (1\ x\ 0.25\ x\ \frac{0.43\ m/s^2}{2\ x\ 9.81\ m/s2})$$

$= \mathbf{0{,}0024\ m}$

∑Hf minor

Hf_{minor} = Hf minor check valve + Hf minor increaser

= 0,0188 m + 0,0024 m

$= \mathbf{0{,}0212\ m}$

∑Hf discharge

Hfd = Hf mayor + Hf minor

= 0.003 m + 0.0212 m

= 0.02 m

3. Perhitungan Head total

Head total = Head statis + ∑Hf suction + ∑Hf discharge

= 4,64 m + 0,07 m + 0,02

= 4,73 m

4. Perhitungan Head pompa

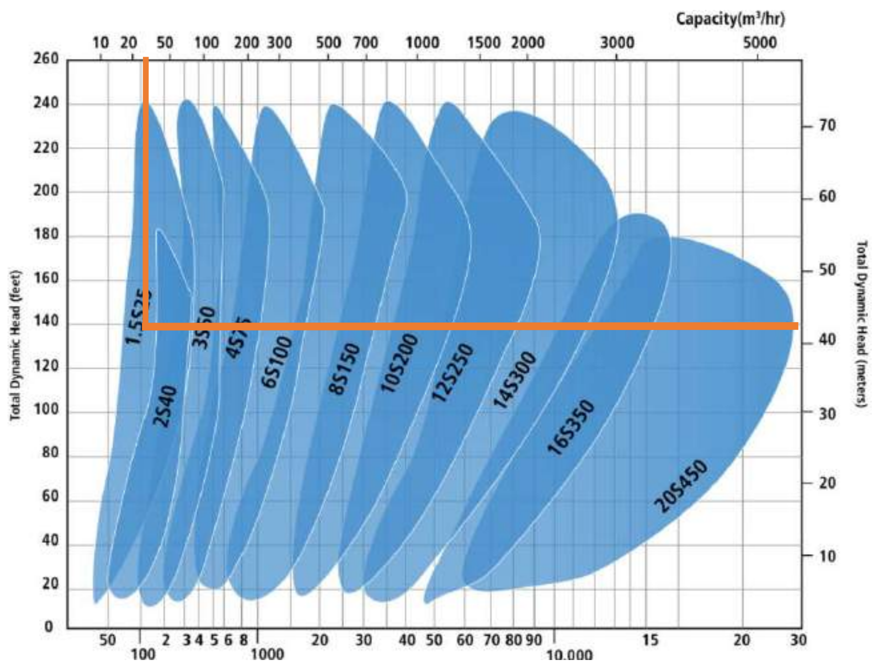
Head pompa = Head statis + L suction + L discharge

= 4,64 m + 34,85 m + 2,63 m

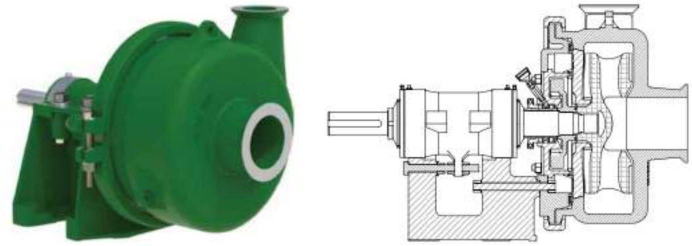
= 42,12 m

Head pompa > Head total

42,12 m > 4,73 m (memenuhi persyaratan)



Berdasarkan grafik di atas, maka dipilih pompa dengan merek Schurco *Slurry Pump* S Series tipe 1,5S25 dengan spesifikasi yang tertera pada lampiran A.



Perhitungan Pompa Sludge menuju SDB

- **Kriteria Perencanaan**
  - K Elbow 90^0 = 0,9
  - K Tee = 1,25

  (*Sumber: Dake, J.M.K., Endang P. Tachyan dan Y.P. Pangaribuan, 1985. "Hidrolika Teknik* Edisi II", Erlangga. Jakarta)
  - K Increaser = 0,25

  (*Sumber: Practical Hydrolics For The Public Work Engineer, 1968*)

- **Data perencanaan**
  - Elbow 90^0 suction = 3 buah
  - Elbow 90^0 discharge = 3 buah
  - Increaser suction = 1 buah
  - Increaser discharge = 1 buah
  - Tee = 3 buah
  - Q bak = 0,000103 m^3/s $\rightarrow$ 0,37 m^3/jam
  - L suction = 44,67 m
  - L discharge = 20,20 m
  - Diameter pipa = 0,03 m $\rightarrow$ 1 inch
  - Kecepatan pipa (v) = 0,42 m/s
  - Head statis = 4,20 m

- **Perhitungan**
  1. Perhitungan suction

     Headloss mayor

Hf $= \frac{10.7\ x\ L\ x\ Q^{1.85}}{C^{1.85}\ x\ D^{4.87}}$

$= \frac{10.7\ x\ 44,67\ m\ x\ (0.000103\ m3/detik)^{1.85}}{130^{1.85}\ x\ 0.03\ m^{4.87}}$

= 0,1433 m

Headloss minor (elbow 90^0)

Hf_{elbow} $= n\ x\ k\ x\ \frac{v^2}{2g}$

Hf_{elbow} $= (3\ x\ 0.9\ x\ \frac{0.42\ m/s^2}{2\ x\ 9.81\ m/s2})$

= 0,0243 m

Headloss minor (increaser)

$Hf_{increaser} = n\ x\ k\ x\ \frac{v^2}{2g}$

$Hf_{increaser} = (1\ x\ 0.25\ x\ \frac{0.42\ m/s^2}{2\ x\ 9.81\ m/s2})$

= 0,0022 m

Headloss minor (Tee)

Hf_{tee} $= n\ x\ k\ x\ \frac{v^2}{2g}$

Hf_{tee} $= (1\ x\ 1,25\ x\ \frac{0.42\ m/s^2}{2\ x\ 9.81\ m/s2})$

= 0,0112 m

∑Hf minor

Hf_{minor} = Hf minor elbow 90^0 + Hf minor increaser + Hf minor tee

= 0,0243 m + 0,0022 m + 0,0112 m

= 0,0378 m

∑Hf suction

Hfs = Hf mayor + Hf minor

= 0,1433 m + 0,0378 m

= 0,1811 m

2. Perhitungan Discharge

Headloss mayor

Hf $= \frac{10.7\ x\ L\ x\ Q^{1.85}}{C^{1.85}\ x\ D^{4.87}}$

$= \frac{10.7\ x\ 20{,}20\ m\ x\ (0.000103\ m3/detik)^{1.85}}{130^{1.85}\ x\ 0.03\ m^{4.87}}$

= 0,0648 m

Headloss minor (elbow 90^0)

Hf_{elbow} = n x k x $\frac{v^2}{2g}$

Hf_{elbow} = (1 x 0,9 x $\frac{0.42\ m/s^2}{2\ x\ 9.81\ m/s2}$)

= 0,0243 m

Headloss minor (increaser)

$Hf_{increaser}$ = n x k x $\frac{v^2}{2g}$

$Hf_{increaser}$ = (1 x 0.25 x $\frac{0.42\ m/s^2}{2\ x\ 9.81\ m/s2}$)

= 0,0022 m

Headloss minor (Tee)

$Hf_{increaser}$ = n x k x $\frac{v^2}{2g}$

$Hf_{increaser}$ = (2 x 1,25 x $\frac{0.42\ m/s^2}{2\ x\ 9.81\ m/s2}$)

= 0,0225 m

∑Hf minor

Hf_{minor} = Hf minor elbow 900 + Hf minor increaser + Hf minor tee

= 0,0243 m + 0,0022 m + 0,0225 m

= 0,0265 m

∑Hf discharge

Hfd = Hf mayor + Hf minor

= 0.0648 m + 0.0265 m

= 0.0913 m

3. Perhitungan Head total

Head total = Head statis + ∑Hf suction + ∑Hf discharge

= 4,20 m + 0,1811 m + 0,0913 m

= 4,47 m

4. Perhitungan Head pompa

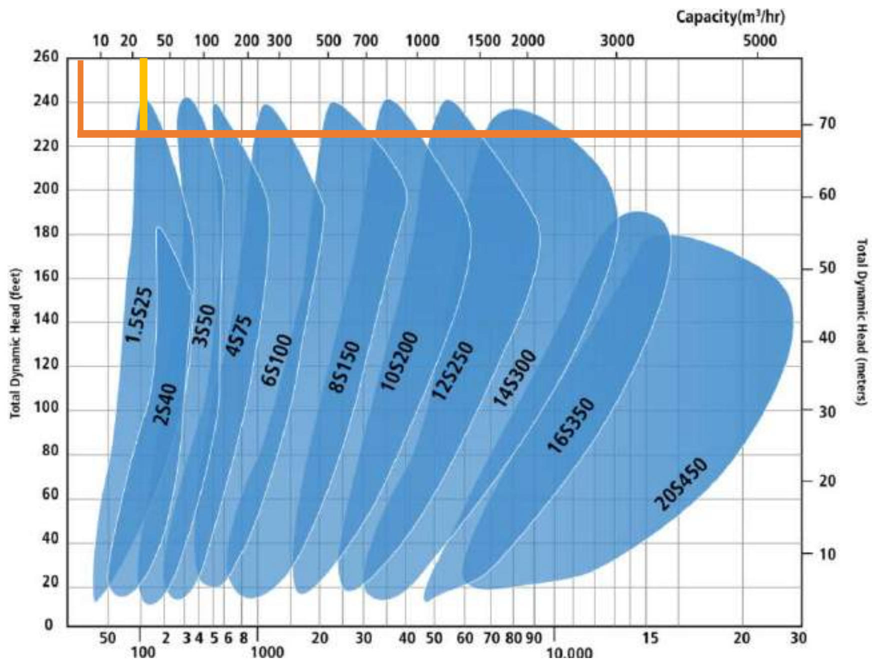
Head pompa = Head statis + L suction + L discharge

= 4,20 m + 44,67 m + 20,20 m

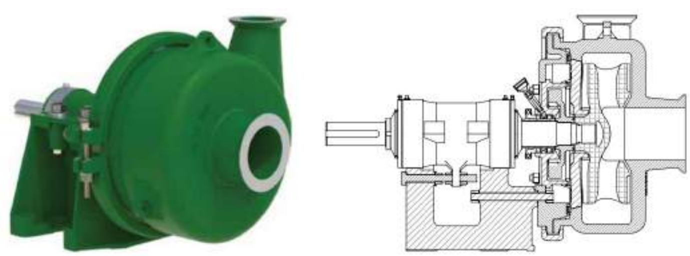
= 69,07 m

Head pompa > Head total

69,07 m > 4,47 m (memenuhi persyaratan)



Berdasarkan grafik di atas, maka dipilih pompa dengan merek Schurco *Slurry Pump* S Series 1,5S25 dengan spesifikasi yang tertera pada lampiran A.



- **Resume**
  - Zona Settling:

    Diameter bak = 7,5 m

    Tinggi bak = 3,5 m

Diameter inlet well = 1,5 m

- Pipa Inlet

  Diameter pipa inlet = 10 inch

- Zona Sludge

  Tinggi zona sludge = 0,7 m

  Tinggi thickening = 2,41 m

- Zona Outlet

  Panjang pelimpah = 23,55 m

  Jumlah V notch = 47 buah

  Tinggi limpasan air = 0,14 m → 14 cm

  Tinggi total saluran pelimpah = 0,18 m

  Tinggi air saluran pelimpah = 0,15 m

  Lebar saluran pelimpah = 0,29 m

- Pipa Outlet

  Diameter pipa outlet = 8 inch

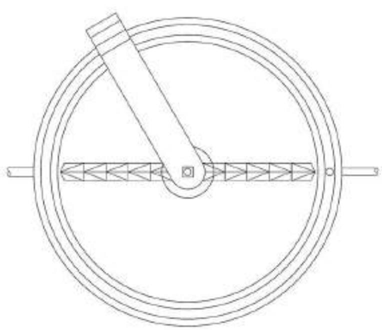
  Diameter pipa lumpur total = 10 inch

  Diameter pipa lumpur resirkulasi = 6 inch

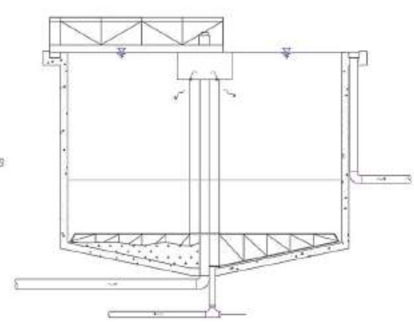
  Diameter pipa lumpur outlet = 8 inch

● Sketsa

- Tampak denah



- Tampak potongan



5.6 *Sludge Drying Bed*

● **Kriteria Perencanaan**

- Waktu pengeringan = 10 - 15 hari

- Tebal *sludge cake* = 20 – 30 cm
- Tebal pasir = 23 – 30 cm
- Lebar = 6 m
- Panjang = 6 – 30 m
- Slope = 1%
- Kecepatan aliran pipa (v) = > 0,75 m/s
- Berat air dalam cake (Pi) = 60% - 70%
- Kadar air (P) = 60% - 80%
- Kadar solid = 20% - 40%
- *Sludge loading rate* = 120 – 150 kg/solid kering/m^2.tahun

  (Sumber : Metcalf & Eddy, Wastewater Engineering Treatment & Reuse, Fourth Edition, hal 1570-1572)

- **Data Perencanaan**
  - Menggunakan 1 unit *sludge drying bed* dengan 3 *bed + 1 bed maintance*
  - Volume lumpur total = bak ekualisasi + *clarifier*

    = 13,97 m^3 + 12,68 m^3

    = 26,65 m^3
  - Tebal pasir = 0,3 m
  - Tebal kerikil = 0,3 m
  - Tebal sludge cake = 0,3 m
  - Waktu pengeringan = 5 hari
  - Berat air dalam cake = 60%
  - Kadar solid = 20%
  - Kadar air (P) = 80%
  - Freeboard = 10%

- **Perhitungan**
  1. Tebal media

     Tebal media = tebal pasir + tebal kerikil + tebal *cake*

     = 0,3 m + 0,3 m + 0,3 m

     = 0,9 m

2. Volume lumpur tiap *bed* (Vb)

Vb $= \frac{Vol.\ lumpur\ total}{jumla\quad bed}$

$= \frac{26{,}65\ m^3}{3}$

= 8,88 m^3/hari

3. Debit Pipa Inlet

Qp = 8,88 **m^3/hari**

= 0,000103 m^3/s

4. Volume sludge *cake* (Vi)

Vi $= \frac{Vb\ (1 - P)}{1 - Pi}$

$= \frac{8{,}88\ \frac{m^3}{har}\ (1 - 80\%)}{1 - 60\%}$

= 4,44 m^3/hari

5. Volume *sludge drying bed* (V)

V = Vi x td

= 4,44 m^3/hari x 5 hari

= 44,42 m^3

6. Dimensi tiap *bed*

A $= \frac{V}{tebal\ cake}$

$= \frac{44{,}42\ m^3}{0{,}3\ m}$

= 148,06 m^2

W **= 6 m**

A = L x W

148,06 m^2 = L x 6 m

L $= \frac{148{,}06\ m^3}{6\ m}$

= 24,68 m → 25 m

7. Volume air (Va)

Va $= \frac{Vol.\ lumpur\ tota\quad (Vi\ x\ td)}{jumla\quad bed}$

$= \frac{26{,}65\ m^3 - (4{,}44\ \frac{m^3}{hari}\ x\ 1\ hari)}{3}$

= 7,40 m³

8. Kedalaman *underdrain*

H $= \frac{Va}{A}$

$= \frac{7{,}40\ m^3}{148{,}06\ m^2}$

= 0,05 m

9. Kedalaman total

Kedalaman = H total media + H *underdrain*

= 0,9 m + 0,05 m

= 0,95 → 1 m

H bangunan = H air + *freeboard*

= 1 m + (20% x 1 m)

= 1,2 m

10. Diameter pipa *underdrain*

Q $= \frac{Va}{td}$

$= \frac{7{,}4\ m^3}{3600\ detik}$

= 0,0021 m³/detik

D $= \sqrt{\frac{4.Q}{\pi}}$

$= \sqrt{\frac{4\ x\ 0{,}0021}{3{,}14}}$ **= 0,0051 m → 51 mm**

Berdasarkan pipa yang ada dipasaran, didapatkan diameter sebesar **60 mm** atau **inch** merk rucika.

KELAS D

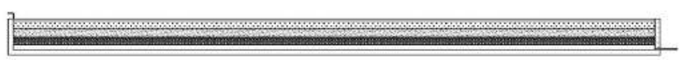
Diameter		Tebal Dinding (mm)	Panjang (m)	Sistem Penyambungan	Kode Produk
inch	mm				
1-1/4	42	1,30	4	SC	510042001
1-1/2	48	1,30	4	SC	510048001
2	60	1,30	4	SC	510060001
2-1/2	76	1,40	4	SC	510076001
3	89	1,60	4	SC	510089001
4	114	2,00	4	SC	510114001
5	140	2,60	4	SC	510140001
6	165	3,00	4	SC	510165001
8	216	4,20	4	SC	510216001
10	267	5,20	4	SC	510267001
12	318	6,20	4	SC	510318001

SC : Solvent Cement (Penyambungan dengan Lem)

- Resume
  - Jumlah bed = 4 buah
  - Tebal Pasir = 0,3 m
  - Tebal Kerikil = 0,3 m
  - Tebal *Cake* = 0,3 m
  - Panjang (L) = 25 m
  - Lebar (W) = 6 m
  - Tinggi total (H) = 1,2 m
  - Diameter pipa *underdrain* = 2 inch

- Sketsa
  - Tampak denah

  - Tampak potongan



BAB 6
PROFIL HIDROLIS

1. Saluran Pembawa dan *Bar Screen*

Direncanakan bangunan diletakkan di atas permukaan tanah

- Kedalaman total = 0,22 m
- Kedalaman air = 0,18 m
- *Freeboard* = 0,04 m
- Tebal dinding = 0,2 m
- Elevasi awal = 0 m

Tinggi bangunan = elevasi awal + (kedalaman total + tebal dinding)
= 0 m + (0,22 m + 0,2 m)
= + 0,42 m (di atas permukaan tanah)

Level muka air = elevasi awal - kedalaman air + tebal dinding
= 0 m + 0,18 m + 0,2 m
= + 0,38 m (di atas muka tanah)

2. Bak Ekualisasi

Direncanakan bangunan diletakkan di bawah permukaan tanah

- Kedalaman total = 3,93 m
- Kedalaman air = 3,43 m
- *Freeboard* = 0,5 m
- Tebal dinding = 0,2 m
- Elevasi awal = 0 m

Tinggi bangunan = elevasi awal – (kedalaman total + tebal dinding)
= 0 m – (3,93 m + 0,2 m)
= - 4,13 m (di bawah permukaan tanah)

Level muka air = elevasi awal - *freeboard*
= 0 m – 0,5 m

= - 0,5 m (di bawah permukaan tanah)

3. Sedimentasi

- ***Zona settling***

Direncanakan bangunan diletakkan di bawah permukaan tanah

- H total = 3,3 m
- H air = 3 m
- *Freeboard* = 0,3 m
- Tebal dinding = 0,2 m
- Elevasi awal = 2,5 m

Tinggi bangunan = elevasi awal - (H total + tebal dinding)
= 2,5 m - (3,3 m + 0,2 m)
= -1 m (di bawah permukaan tanah)

Level muka air = elevasi awal - *freeboard*
= 2,5 m – 0,3 m
= + 2,2 m (di atas permukaan tanah)

- ***Zona sludge***

Direncanakan bangunan diletakkan di bawah permukaan tanah

- H total = 2 m
- Tebal dinding = 0,2 m
- Elevasi awal = -0,8 m

Tinggi bangunan = elevasi awal - (H total + tebal dinding)
= -0,8 m - (2 m + 0,2 m)
= -3 m (di bawah permukaan tanah)

- ***Zona pelimpah***

Direncanakan bangunan diletakkan di atas permukaan tanah

- H total = 0,1 m
- H air zona settling = 2,2 m

- H air limpahan = 0,05 m
- Tebal dinding = 0,2 m
- Elevasi awal = 0,8 m

Tinggi bangunan awal = H air zona settling - H air limpahan – tebal dinding

= 2,2 m - 0,05 m – 0,2

= + 1,95 m (di atas permukaan tanah)

- **Zona *Outlet***

Direncanakan bangunan diletakkan di bawah permukaan tanah

- H total = 3,3 m
- H air = 3 m
- *Freeboard* = 0,3 m
- Tebal dinding = 0,2 m
- Elevasi awal = 2,5 m

Tinggi bangunan = elevasi awal - (H total + tebal dinding)

= 2,5 m - (3,3 m + 0,2 m)

= -1 m (di bawah permukaan tanah)

Level muka air = elevasi awal - *freeboard*

= 2,5 m – 0,3 m

= + 2,2 m (di atas permukaan tanah)

4. *Activated Sludge*

Direncanakan bangunan diletakkan di bawah permukaan tanah

- Kedalaman tangki = 6,6 m
- Kedalaman air = 6 m
- *Freeboard* = 0,6 m
- Tebal dinding = 0,2 m
- Elevasi awal = 2 m

Tinggi bangunan = elevasi awal - (kedalaman total + tebal dinding)

= 2 m - (6,6 m + 0,2 m)

= - 4,8 m (di bawah permukaan tanah)

Level muka air = elevasi awal - *freeboard*

= 2 m - 0,6 m

= + 1,4 m (di atas permukaan tanah)

5. Bak Pengendap (*Clarifier*)

Direncanakan bangunan diletakkan di atas permukaan tanah

- Kedalaman tangki = 5,94 m
- Kedalaman air = 5,91 m
- *Freeboard* = 0,03 m
- Tebal dinding = 0,2 m
- Elevasi awal = 2 m

Tinggi bangunan = elevasi awal + (kedalaman tangki + tebal dinding)

= 2 m - (5,94 m + 0,2)

= - 4,14 m (di bawah permukaan tanah)

Level muka air = elevasi awal - *freeboard*

= 2 m - 0,03 m

= +1,97 m (di atas permukaan tanah)

6. *Sludge Drying Bed*

Direncanakan bangunan diletakkan di bawah permukaan tanah

- Kedalaman total = 1,2 m
- *Freeboard* = 0,1 m
- Tebal *cake sludge* = 0,3 m
- Tebal dinding = 0,2 m
- Elevasi awal = 0 m

Tinggi bangunan = elevasi awal - (kedalaman total + tebal dinding)

= 0 m - (1,2 m + 0,2 m)

= - 1,4 m (di bawah permukaan tanah)

Level muka media = elevasi awal – (*freeboard* + tebal *cake sludge*)

= 0 m - (0,1 m + 0,3 m)

= - 0,4 (di bawah permukaan tanah)

BAB 7

BILL OF QUANTITY (BOQ) DAN RENCANA ANGGARAN BIAYA (RAB)

7.1 *Bill of Quantity* (BOQ)

Perhitungan *Bill of Quantity* ini digunakan dalam menentukan kuantitas perencanaan kebutuhan apa saja dalam pembangunan Instalasi Pengolahan Air Limbah (IPAL) Industri Kayu Lapis, mulai dari kebutuhan persiapan, pengerjaan *site*, dan semua fasilitas pendukung yang dibutuhkan, berikut BOQ Perencanaan Instalasi Pengolahan Air Limbah (IPAL) Industri Kayu Lapis:

Tabel 7. 1 BOQ Pembetonan

BOQ PEMBETONAN										
Perencanaan					Setelaah pembetonan					Volume Beton
P (m)	L (m)	T (m)	Ø (m)	V (m3)	P (m)	L (m)	T (m)	Ø (m)	V (m3)	V2 - V1
Saluran Pembawa dan Screen										
2,50	0,18	0,22	-	0,10	2,50	0,58	0,42	-	0,61	0,51
Bak Ekualisasi										
6,00	3,00	3,00	-	54,00	6,40	3,40	3,00	-	65,28	11,28
Bak Pengendap 1 Zona Settling										
10,50	3,50	3,30	-	121,28	10,70	3,90	3,50	-	146,06	24,78
Bak Pengendap 1 Zona Sludge										
4,00	3,50	2,00	-	18,16	4,4	3,9	2,20	-	24,59	6,43
3,00	3,00		-		3,4	3,4		-		
Bak Pengendap 1 Zona Outlet										
0,75	3,50	3,30	-	8,66	0,95	3,90	3,50		12,97	4,31
Total Pembetonan Bak Pengendap 1										35,51
Activated Sludge										
18,00	9,00	6,60	-	1069,20	18,40	9,60	6,80	-	1201,15	131,95
Bak Pengendap 2 Zona Settling										
-	-	3,50	7,50	154,55	-	-	3,50	7,90	171,47	16,92
Bak Pengendap 2 Zona Thickening										
-	-	1,71	7,50	75,51	-	-	1,71	7,90	83,78	8,27
Bak Pengendap 2 Zona Sludge										
-	-	0,70	-	17,40	-	-	0,90		22,40	5,00
Bak Pengendap 2 Zona Outlet										
23,55	0,29	0,18	-	1,22	23,55	0,69	0,38	-	6,16	4,93
Total Pembetonan Bak Pengendap 2										35,13
Sludge Drying Bed (SDB)										
49,36	6,00	1,20	-	355,39	49,76	6,40	1,40	-	445,85	90,46
Total Pembetonan Sludge Drying Bed (SDB) 4 Bed										361,83
TOTAL BOQ PEMBETONAN										576,21

Tabel 7. 2 BOQ Galian

BOQ GALIAN				
Panjang (m)	Lebar (m)	Tinggi (m)	Diameter (m)	Volume (m3)
Bak Ekulisasi				
6,40	3,40	3,00	-	65,28
Bak Pengendap 1 Zona Settling				
10,70	3,90	1,00	-	41,73
Bak Pengendap 1 Zona Sludge				
4,40	3,90	2,20		24,59
3,40	3,40			
Bak Pengendap 1 Zona Outlet				
0,95	3,90	1,00	-	3,71
Total Galian Bak Pengendap 1				70,03
Activated Sludge				
18,40	9,60	4,80	-	847,87
Bak Pengendap 2 Zona Settling				
-	-	1,53	7,90	74,96
Bak Pengendap 2 Zona Thickening				
-	-	1,71	7,90	83,78
Bak Pengendap 2 Zona Sludge				
-	-	0,90	-	22,40
Total Galian Bak Pengendap 2				181,13
Sldge Drying Bed 4 unit				
49,76	6,40	1,4	-	445,85
TOTAL BOQ GALIAN				1610,16

7.2 Rencana Anggaran Biaya (RAB)

Rencana Anggaran Biaya merupakan suatu perkiraan kebutuhan biaya yang diperlukan dalam melaksanakan suatu kegiatan pelaksanaan pekerjaan. Rencana Anggaran Biaya (RAB) disusun berdasarkan harga satuan pekerjaan dan volume pekerjaan yang dilaksanakan sesuai dengan bentuk dan ukuran yang telah direncanakan. Rencana Anggaran Biaya pada pembangunan Perencanaan Instalasi Pengolahan Air Limbah (IPAL) Industri Kayu Lapis sebagai berikut:

Tabel 7. 3 RAB Aksesoris Bnngunan

RAB Aksesoris Bangunan							
Uraian	Uk	Satuan	Jml	Satuan	Harga Satuan	Estimasi Harga	Harga Total Sub Unit
Saluran Pembawa dan Screen							
Kisi	5	mm	5	Kisi	Rp100.000	Rp500.000,00	Rp500.000,00
Bak Ekualisasi							
Pompa Centrifugal	-	-	1	buah	Rp5.672.100	Rp5.672.100,00	Rp21.232.419,00
Pipa PVC D (4 m)	8	inch	3	buah	Rp719.600	Rp1.926.729,00	
Increaser	-	-	2	buah	Rp154.000	Rp308.000,00	
Elbow 90	?	-	3	buah	Rp217.530	Rp652.590,00	
Klem pipa	-	-	3	Buah	Rp91.000	Rp273.000,00	
Surface Aerator (SAR-330)	-	-	1	Buah	Rp6.000.000	Rp6.000.000,00	
Flow mater	-	-	1	buah	Rp6.400.000	Rp6.400.000,00	
Bak Pengendap 1							
Pipa PVC D (4 m)	8	inch	1	buah	Rp719.600	Rp719.600,00	Rp7.319.600,00
Plate Settler	-	-	46	buah	Rp100.000	Rp4.600.000,00	
Gutter	-	-	2	buah	Rp1.000.000	Rp2.000.000,00	
Activated Sludge							
Surface Aerator (SAR-325)	-	-	3	buah	Rp5.500.000	Rp16.500.000,00	Rp26.762.927,00
Pipa PVC D (4 m)	10	inch	3	buah	Rp1.185.200	Rp3.937.827,00	
Increaser	-	-	2	buah	Rp154.000	Rp308.000,00	
Elbow 90	-	-	1	buah	Rp345.000	Rp345.000,00	
Pompa Centrifugal	-	-	1	buah	Rp5.672.100	Rp5.672.100,00	
Bak Pengendap 2							
Skimmer	-	-	1	buah	Rp4.320.000	Rp4.320.000,00	Rp12.910.400,00
Tee	-	-	1	buah	Rp878.900	Rp878.900,00	
Elbow 90	-	-	2	buah	Rp88.500	Rp177.000,00	
Increaser	-	-	3	buah	Rp154.000	Rp462.000,00	
Pipa PVC D (4 m)	6	inch	8	buah	Rp409.200	Rp3.273.600,00	
	0,75	inch	2	buah	Rp38.400	Rp76.800,00	
Pompa Centrifugal	-	-	1	buah	Rp5.672.100	Rp5.672.100,00	
Motor penggerak	-	-	1	buah	Rp2.050.000	Rp2.050.000,00	
Sludge Drying Bed							
Tee	-	-	4	buah	Rp5.500	Rp22.000,00	Rp12.074.464,00
Elbow 90	-	-	4	buah	Rp6.500	Rp26.000,00	
Increaser	-	-	3	buah	Rp11.000	Rp33.000,00	
Pipa PVC D (4 m)	2	Inch	4	buah	Rp115.300	Rp461.200,00	
	1	inch	2	buah	Rp52.500	Rp105.000,00	
	0,75	inch	7	buah	Rp38.400	Rp268.800,00	
Pompa Centrifugal	-	-	1	buah	Rp5.672.100	Rp5.672.100,00	
Pasir	-	-	14,808	m3	Rp221.200	Rp3.275.529,60	
Kerikil	-	-	14,808	m3	Rp149.300	Rp2.210.834,40	
Total RAB Aksesoris Bangunan IPAL							Rp84.799.810,00

Tabel 7. 4 Detail RAB RAW Pembetonan dan Galian (HSPK)

Untuk membuat 1 m3 dinding beton bertulang (200 kg Besi + bekisting)							
No	Uraian	Koef.	Jml Unit	Total	Satuan	Harga Satuan (Rp)	Total Harga Satuan (Rp)
1	Semen PC 40 kg	8,4	1	8,4	zak	Rp 63.000	Rp 529.200
2	Pasir Cor	0,54	1	0,54	m3	Rp 265.300	Rp 143.262
3	Batu Pecah Mesin 1/2 cm	0,81	1	0,81	m3	Rp 243.300	Rp 197.073
4	Besi Beton Polos	210	1	210	kg	Rp 13.500	Rp 2.835.000
5	Paku Usuk	3	1	3	kg	Rp 14.800	Rp 44.400
6	Plywood Uk. 122x244x9 mm	2,5	1	2,5	Lembar	Rp 105.000	Rp 262.500
7	Kawat Beton	3	1	3	kg	Rp 25.900	Rp 77.700
8	Kayu Meranti Bekisting	0,25	1	0,25	m3	Rp 622.500	Rp 905.625
9	Kayu meranti balok 4/6, 5/7	0,105	1	0,105	m3	Rp 4.968.000	Rp 521.640
10	Minyak Bekisting	1,2	1	1,2	Liter	Rp 30.100	Rp 36.120
TOTAL RINCIAN BIAYA							Rp 4.994.760
Pekerjaan dinding beton (200 kg Besi + Bekisting)							
No	Uraian	Koefisien	Jumlah	Total	Satuan	Harga Satuan (Rp)	Total Harga Satuan (Rp)
1	Mandor	0,323	1	0,323	oh	Rp 180.000	Rp 58.140
2	Tukang	1,56	1	1,56	oh	Rp 165.000	Rp 257.400
3	Tukang	1,4	1	1,4	oh	Rp 165.000	Rp 231.000
4	Tukang	0,275	1	0,275	oh	Rp 165.000	Rp 45.375
5	Pembantu tukang	5,65	1	5,65	oh	Rp 155.000	Rp 875.750
TOTAL RINCIAN BIAYA							Rp 1.467.665
Pekerjaan Galian tanah Biasa							
No	Uraian	Koefisien	Jumlah	Total	Satuan	Harga Satuan (Rp)	Total Harga Satuan (Rp)
1	Mandor	0,025	1	0,025	oh	Rp 180.000	Rp 4.500
2	Pembantu tukang	0,75	1	0,75	oh	Rp 155.000	Rp 116.250
TOTAL RINCIAN BIAYA							Rp 120.750

Tabel 7. 5 RAB Pra Kontruksi

RAB PRA KONTRUSKSI				
Uraian	Jumlah	Satuan	Harga Satuan	Estimasi Harga
Papan Nama	1	unit	Rp350.000	Rp350.000
Administrasi dan Dokumentasi	1	paket	Rp5.000.000	Rp5.000.000
Paket K3	1	paket	Rp6.883.000	Rp6.883.000
Total RAB Pra Kontruksi				Rp12.233.000

Tabel 7. 6 RAB Pembetonan

RAB PEMBETONAN				
Uraian	Jumlah	Satuan	Harga Satuan	Estimasi Harga
Pembetonan Saluran Pembawa dan Screen	0,51	m3	Rp4.994.760	Rp2.547.327,60
Pembetonan Bak Ekualisasi	11,28	m3	Rp4.994.760	Rp56.340.892,80
Pembetonan Bak Pengendap 1	35,51	m4	Rp4.994.760	Rp177.379.106,69
Pembetonan Activated Sludge	131,95	m3	Rp4.994.760	Rp659.068.571,52
Pembetonan Bak Pengendap 2	35,13	m3	Rp4.994.760	Rp175.455.760,47
Pembetonan Sludge Drying Bed	361,83	m3	Rp4.994.760	Rp1.807.256.008,70
Total RAB Pembetonan IPAL				Rp2.878.047.667,78

Tabel 7. 7 RAB Pekerjaa Galian

RAB GALIAN				
Uraian	Jumlah	Satuan	Harga Satuan	Estimasi Harga
Galian Bak Ekualisasi	65,28	m3	Rp160.760	Rp10.494.412,80
Galian Activated Sludge	847,87	m3	Rp160.760	Rp136.303.902,72
Galian Bak Pengendap 2	181,13	m3	Rp160.760	Rp29.119.036,57
Galian Sludge Drying Bed	445,85	m3	Rp160.760	Rp71.674.781,70
Buangan Tanah Galian	1540,14	m3	Rp29.915	Rp46.073.144,33
Total RAB Galian IPAL				Rp247.592.133,79

Tabel 7. 8 RAB Tenaga Kerja

RAB TENAGA KERJA (SDM DAN NON-SDM)						
Uraian	Harga Satuan	Satuan	Jumlah	Estimasi Harga	Periode Kerja (Hari)	Harga Total
Tim Humas dan Administrasi	Rp500.000	OH	10	Rp5.000.000	3	Rp15.000.000
Kontruktor	Rp1.000.000	OH	5	Rp5.000.000	10	Rp50.000.000
Mandor Penggalian	Rp180.000	OH	4	Rp720.000	5	Rp3.600.000
Pembantu Tukang galian	Rp155.000	OH	15	Rp2.325.000	10	Rp23.250.000
Mandor Pembetonan K-275	Rp180.000	OH	4	Rp720.000	5	Rp3.600.000
Tukang Pembetonan K-275	Rp165.000	OH	10	Rp1.650.000	15	Rp24.750.000
Pembantu Tukang K-275	Rp155.000	OH	5	Rp775.000	15	Rp11.625.000
Mandor Perpipaan	Rp180.000	OH	4	Rp720.000	3	Rp2.160.000
Tukang Perpipaan	Rp165.000	OH	8	Rp1.320.000	5	Rp6.600.000
Pembantu Perpipaan	Rp155.000	OH	2	Rp310.000	5	Rp1.550.000
Mandor kelistrikan	Rp180.000	OH	2	Rp360.000	3	Rp1.080.000
Pembantu Tukang Kelistrikan	Rp155.000	OH	2	Rp310.000	5	Rp1.550.000
Dump Truck 4 x 2	Rp1.680.000	Hari	5	Rp8.400.000	3	Rp25.200.000
Excavator	Rp3.679.992	Hari	3	Rp11.039.976	2	Rp22.079.952
Total RAB Tenaga Kerja (SDM dan Non-SDM)						Rp192.044.952

Tabel 7. 98 Total RAB IPAL

TOTAL RAB IPAL	
Uraian	Harga Sub RAB
Total RAB Aksesoris Bangunan IPAL	Rp75.879.810,00
Total RAB Pembetonan IPAL	Rp2.878.047.667,78
Total RAB Galian IPAL	Rp247.592.133,79
Total RAB Pra Kontruksi	Rp12.233.000
Total RAB Tenaga Kerja (SDM dan Non-SDM)	Rp192.044.952
TOTAL	Rp3.405.797.563,57